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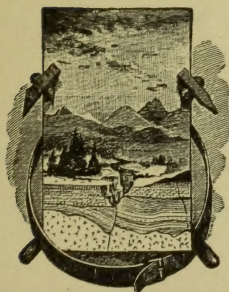
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 341

CONTRIBUTIONS
TO
ECONOMIC GEOLOGY
1907

PART II.—COAL AND LIGNITE

MARIUS R. CAMPBELL
GEOLOGIST IN CHARGE



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CONTRIBUTIONS TO ECONOMIC GEOLOGY, 1907, PART II.

COAL AND LIGNITE.

MARIUS R. CAMPBELL, *Geologist in Charge.*

INTRODUCTION.

By MARIUS R. CAMPBELL.

GENERAL STATEMENT.

During the year 1907 a greater addition was made to existing knowledge regarding the outline, extent, quality, and tonnage of the western coal fields than had been made in any previous year. This was due largely to the fact that during the latter part of 1906 and the early part of 1907 supposed coal lands to the extent of 67,000,000 acres, or 104,000 square miles, were withdrawn from entry, and the United States Geological Survey was called upon to examine and to classify these lands so that they might be restored to coal entry.

Before this work was done it was impossible to determine with any degree of accuracy the positions of many of the coal fields in the Rocky Mountain region, or to say what were their sizes and shapes and the extent of their coal resources. Now, however, the coal areas are much better known, and a map representing them has been prepared.^a A copy of this map on a small scale, in black and white, is here given (Pl. I) for the purpose of showing the extent of the coal fields and the areas in which surveys were carried on during the last year.

In preparing this map it was deemed necessary to revise and systematize the nomenclature of the coal areas. Accordingly a committee consisting of George H. Ashley, Joseph A. Taff, and

^a Map of coal fields of the United States, U. S. Geol. Survey, 1908

Alfred R. Schultz was appointed to consider this question and make recommendations which should govern the practice of the Geological Survey. The report of this committee, in brief, provides for the recognition of four classes of areas, as follows:

1. *Coal province*.—This corresponds in a general way with a geologic or physiographic province. In order from east to west the coal provinces of the United States are the Eastern, Interior, Gulf, Northern Great Plains, Rocky Mountain, and Pacific Coast.

2. *Coal region*.—This term is to be applied to a part of a province which has a uniform geologic history and topographic expression, and which is manifestly too large to be considered as a coal field. In the Eastern coal province the following coal regions are recognized: Atlantic Coast, Anthracite, and Appalachian. In the Interior: Eastern, Northern, Western, and Southwestern. In the Northern Great Plains: Fort Union, Assiniboine, and Black Hills. In the Rocky Mountain: San Juan River, Southwestern Utah, Raton Mountain, Denver, Uinta, Green River, Bighorn Basin, and Judith Basin.

3. *Coal field*.—A coal field is defined as (a) an isolated area that is essentially a geologic and topographic unit, or (b) an arbitrary part of an extended coal region that for economic or geologic reasons may be considered a unit, separate and apart from the rest of the region. The Southern Anthracite, Cahaba, Bull Mountain, Great Falls, Hanna, Canon City, Cerrillos, Roslyn, and Coos Bay fields are examples of the first class; and the Pittsburg, New River, Pocahontas, and Belleville fields are examples of the second class.

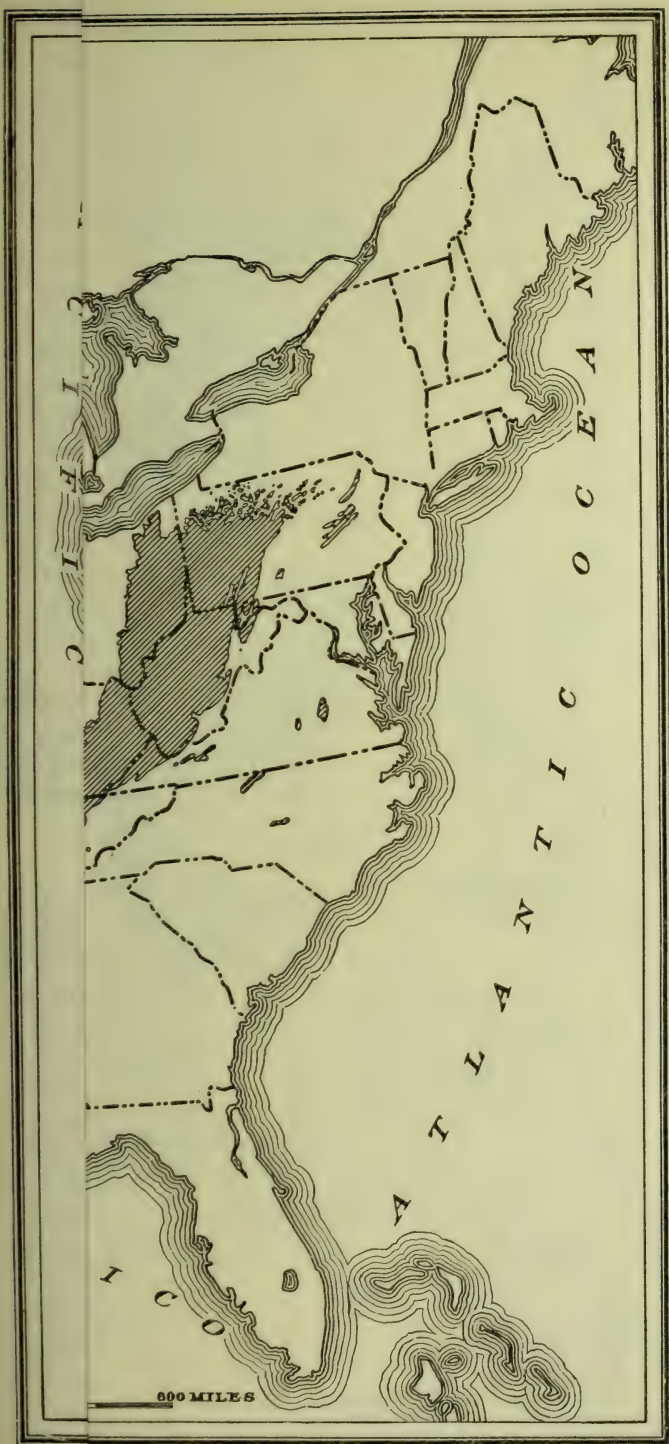
4. *Coal district*.—This is recognized as a subdivision of a field. Its limits are generally controlled by commercial conditions, and it marks a center of development and production.

A novel feature of the new coal map is the attempt to represent many of the great structural basins of the Rocky Mountains as coal bearing, although the coal in the center of the basin is in many places so deeply covered by later barren sediments that it is not available at the present time, and in some basins it is even doubtful if it can ever be mined. The main difference, however, in the outline of the coal fields here shown, as compared with those represented on any previous map, is due to the increased knowledge already referred to, which is more fully presented in the various papers constituting this volume.

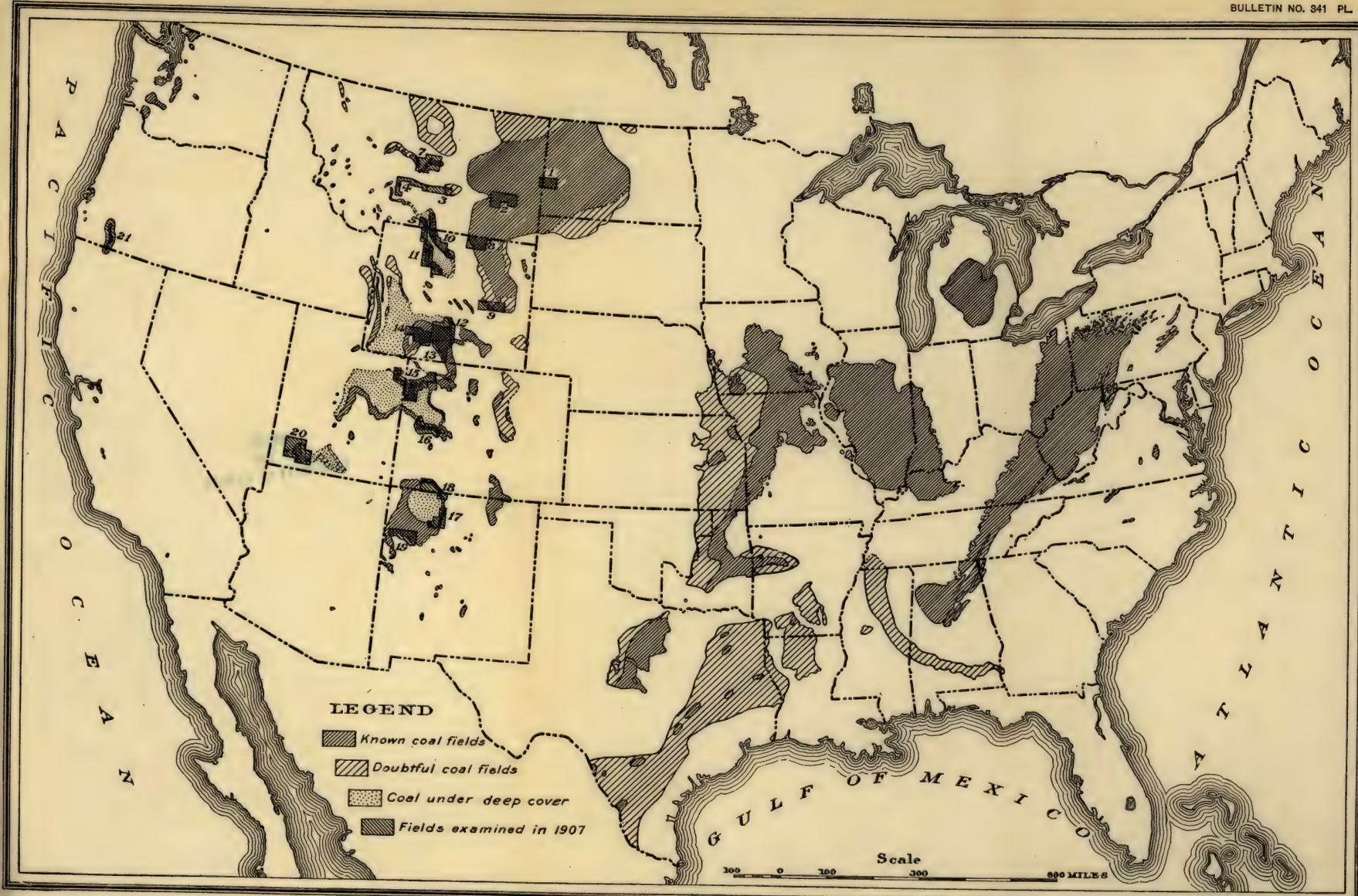
GEOLOGIC WORK.

GENERAL OUTLINE.

Early in June, 1907, sixteen geologic parties were outfitted and placed in the field, in the States of North Dakota, Montana, Wyoming, Colorado, Utah, and New Mexico, to classify as much of the land which had previously been withdrawn by departmental orders as time and means would permit. In all about 20,000 square miles were



Ft. Dodge, Montana; 7, Lewistown, Montana; 8, Sheridan, Wyoming; 13, Little Snake River, Wyoming; 14, Rock; 16, 18, Durango, Colorado-New Mexico; 19, San Juan



MAP SHOWING COAL FIELDS OF THE UNITED STATES.

Fields surveyed in 1907: 1, Sentinel Butte, North Dakota-Montana; 2, Miles City, Montana; 3, Bull Mountain, Montana; 4, Crazy Mountains, Montana; 5, Red Lodge, Montana; 7, Lewistown, Montana; 8, Sheridan, Wyoming; 9, Glenrock, Wyoming; 10, Bighorn Basin, northeast side, Wyoming; 11, Bighorn Basin, southwest side, Wyoming; 12, Great Divide Basin, Wyoming; 13, Little Snake River, Wyoming; 14, Rock Springs, Wyoming; 15, Uinta Basin and Henrys Fork, Colorado-Utah; 16, Grand Mesa, Colorado; 17, San Juan River basin, southeastern part, New Mexico; 18, Durango, Colorado-New Mexico; 19, San Juan River basin, southern part, New Mexico; 20, Harmony, Colob, and Kanab, Utah; 21, Rogue River Valley, Oregon.

examined and classified. The work was done with two purposes in view, namely, (1) to classify the land for the purpose of restoring it to coal entry, and (2) to obtain information regarding the accessibility of the fields, quality of coal, correlation of coal beds, and in fact all data of a geologic and economic character.

It is proposed to publish detailed reports of the work of each party containing the information thus accumulated; but inasmuch as many of these reports could not be written until the completion of the work it has been thought best to prepare a preliminary statement containing a brief account of the investigation made by each party during the year. These papers, which make up the present volume, give only the more important and obvious facts for immediate use. Similar reports were published in Bulletin 316, descriptive of fields examined during the year 1906-7, and in Bulletin 285, relative to fields examined in the year 1905-6. The maps accompanying this volume are necessarily on a small scale and incomplete, but the full reports on each field will contain contour maps in colors, on a uniform scale of 1 to 125,000.

The field work on which these reports are based consisted of tracing and mapping outcrops of the various geologic formations and coal beds according to land surveys, care being taken to tie such meanders to stones and other monuments marking the section corners; of examining the coal beds wherever possible, to determine the thickness and character of the coal; and of taking samples for chemical analysis.

WESTERN FIELDS.

In some of the Western States the geologic parties were so situated that it was impossible to provide for field supervision except by the writer; hence in a large measure their work was carried on independently of other parties.

In central Montana and northern Wyoming the work of five parties was so closely related that they were placed under the direct supervision of Cassius A. Fisher, and similarly four parties in southern Wyoming were placed under the control of A. C. Veatch. Unfortunately during the field season Mr. Veatch was detailed to other work, and the parties previously under his direction carried on their work independently of those in adjacent regions. The work done by the various parties is briefly summarized as follows:

North Dakota.—A party under the joint direction of A. G. Leonard, State geologist, and Carl D. Smith, of the Federal Survey, made an examination of the Sentinel Butte lignite field of western North Dakota. As shown by area No. 1 on Pl. I, work was begun at Medora and carried westward along the Northern Pacific Railway into Montana. Professor Leonard remained with the party only while it was in North Dakota, and after that it was in charge of Mr. Smith. It

was the intention to extend the survey to Glendive, on Yellowstone River, but Mr. Smith was needed to complete work at Miles City, Mont., and consequently the territory examined extended only from Medora to Wibaux, Mont., a little west of the North Dakota line.

Montana.—In Montana six geologic parties were engaged in the study of coal fields during the summer of 1907, as follows:

1. A party under the direction of Arthur J. Collier made a survey of the coal and lignite field in the vicinity of Miles City, on Yellowstone River, as shown by area No. 2 on Pl. I. In the middle of the field season Mr. Collier was called away to other work, and the survey was completed by the union of Mr. Collier's and Mr. Smith's parties under the latter's direction.

2. A party under the supervision of Lester H. Woolsey made a survey of what was supposed to be a coal field along Musselshell River from Shawmut eastward. No coal of workable thickness was found in this region, and late in the season work was begun on the Bull Mountain coal field near Roundup, as shown by area No. 3, Pl. I. This is a promising field, and is likely to be developed in the near future to supply coal to the new line of the Chicago, Milwaukee and St. Paul Railway.

3. A party under the direction of Chester W. Washburne examined the Bridger field of Carbon County, south of Yellowstone River. This is an important field, but the coal of workable thickness does not extend far in either direction. As shown by area No. 10 on Pl. I, Mr. Washburne's field is largely in Wyoming, and consequently his paper is given under that State.

4. Elmer G. Woodruff's party made a detailed survey of the Red Lodge coal field, which includes the recent extensive developments on Bear Creek. This is one of the great coal fields of the State, not so much on account of its area as on account of the number and thickness of the coal beds and the quality of the coal. The field examined by Mr. Woodruff is represented by area No. 5, Pl. I.

5. A party directed by Ralph W. Stone mapped and studied a supposed coal field along Musselshell River from the west line of the field examined by Mr. Woolsey to the head of the stream, and from the divide westward and southward along the Montana Railroad. This field is represented by area No. 4 on Pl. I. Mr. Stone succeeded in showing that this region does not contain workable coal, and consequently can not be counted as a source of supply for the future.

6. A party under the direction of William R. Calvert examined and mapped the Lewistown coal field from a point 20 miles east of Lewistown to the east end of the Little Belt Mountains, where connection was made with the Great Falls field surveyed by Mr. Fisher in 1906. The field examined by Mr. Calvert is represented by area No. 7 on Pl. I.

Wyoming.—In Wyoming seven parties were engaged in studying and mapping the coal fields, which, if area and tonnage are considered, are probably more extensive than the fields of any other State. The fields examined by the various parties are as follows:

1. A party under the direction of Elmer G. Woodruff made an examination of the southwest side of the Bighorn Basin from the Montana line through Cody and Meeteetse nearly to Thermopolis, on Bighorn River, as shown by area No. 11 on Pl. I. For a long time these fields have been practically inaccessible on account of lack of railroad facilities, but recently a branch of the Chicago, Burlington and Quincy Railway has been built up Bighorn River to the south end of the basin, and the country is being rapidly developed.

2. Chester W. Washburne with a party of geologists made an examination of the northeast side of the Bighorn Basin, from the Montana line to a point south of Basin, as shown by area No. 10 on Pl. I. The coal on this side of the basin is not so promising as that described by Mr. Woodruff, but there are a few fields where coal mining doubtless will be carried on, at least to supply the local demand.

3. A party under the direction of Joseph A. Taff studied and mapped a coal field in the vicinity of Sheridan. This field includes the mines at Dietz, Carneyville, and Monarch, and probably equally productive territory to the north and east. The area mapped by Mr. Taff is represented by No. 8 on Pl. I. This field is part of the great Fort Union coal region, which includes a large part of northeastern Wyoming, eastern Montana, and western North Dakota.

4. A party under the leadership of E. Wesley Shaw examined and mapped the extreme south end of the Fort Union coal region near Douglas, on North Platte River. This is known as the Glenrock coal field, and is represented by area No. 9 on Pl. I. Mr. Shaw's report seems to show that the coal beds of the southern point of the Fort Union region are of little value away from the present centers of production at Glenrock and Big Muddy.

5. A party under the direction of Max W. Ball made an examination of the Little Snake River coal field, which lies south of the Union Pacific Railroad and west of the Encampment mining region, and which is represented by area No. 13 on Pl. I. The examination of this field was incomplete, Mr. Ball not having time to extend his work to the eastern margin of the coal field, nor to the Yampa coal field on the south, surveyed by Messrs. Fenneman and Gale in 1905.

6. A party under E. E. Smith examined the northern part of the great coal region along the Union Pacific Railroad, from the railroad northward to the mountain rim which marks the limit of the field. This field occupies almost the entire area of the Great Divide Basin, which, although situated on the Continental Divide, has no outward drainage. The field is represented by area No. 12 on Pl. I.

7. A party under the direction of Alfred R. Schultz made a survey of the coal fields exposed on the north flank of the Rock Springs dome, an uplift near the center of the Green River Basin, which brings to the surface lower and more valuable coal beds than are present in the surrounding region. The field mapped is represented by area No. 14 on Pl. I.

Colorado.—Only three geologic parties were at work during the summer of 1907 in the State of Colorado. The fields examined by them are as follows:

1. A party under the leadership of Hoyt S. Gale continued the mapping of the northern rim of the Uinta Basin from the Danforth Hills to Vernal, Utah, and then made a hurried reconnaissance of the Henrys Fork field, north of Uinta Mountains. The former is the westward extension of fields surveyed by Mr. Gale in 1906 and by Messrs. Fenneman and Gale in 1905. The territory examined is represented by area No. 15 on Pl. I.

2. A party under the direction of Willis T. Lee made an examination of the southern rim of the Uinta Basin from Grand Junction to Somerset. This is generally known as the Grand Mesa field, and is represented as area No. 16 on Pl. I. Generally the coal beds are inaccessible at the present time, but in the vicinity of Somerset a branch line of the Denver and Rio Grande Railroad extends into the coal field and development has begun.

3. A party under the leadership of James H. Gardner examined the Durango coal field from Durango eastward to Lumberton, N. Mex. In 1905 a hurried examination was made by F. C. Schrader^a of the eastern rim of this basin, but no detailed mapping of the outcrop of the coal-bearing formations was attempted. Accordingly during the last season Mr. Gardner made a resurvey of the outcrops for the purpose of more definitely locating them with reference to public-land corners, and of determining the coal resources of the field. The area surveyed is represented by No. 18 on Pl. I.

New Mexico.—In New Mexico only two coal fields were examined during the summer of 1907. These are located on the margin of the San Juan River basin, as follows:

1. A party under the direction of James H. Gardner resurveyed the southeastern rim of the basin from Gallina to Raton Springs, as indicated by area No. 17, Pl. I. This had previously been examined by Mr. Schrader in 1905, but not with sufficient care to classify the land.

2. Mr. Gardner also mapped the southern rim of the basin from Gallup to San Mateo. (See area No. 19, Pl. I.)

Utah.—In Utah the coal fields are fairly well known, except those in the southern part of the State, which have been attracting so much attention in late years that it seemed advisable to examine them.

^a Bull. U. S. Geol. Survey No. 285, 1906, pp. 241-258.

A party under the direction of George B. Richardson made a survey of the so-called anthracite field of Iron County, and then extended its work to the east as far as the season would permit. The territory examined is represented by area No. 20 on Pl. I. According to Mr. Richardson's report, this region is rugged and not easily accessible, but as it is near the San Pedro, Los Angeles and Salt Lake Railroad, it seems possible that it may be extensively developed in the near future, and coal from this field may be taken to the Southwest, where there is a great and growing demand for fuel.

Oregon.—The coal fields of Oregon are neither extensive nor promising. Many occurrences of coal have been noted, but either the beds are too thin for practical mining or the coal is too impure for commercial use. J. S. Diller examined a small coal field in Rogue River valley, east of Medford and Ashland, as shown by No. 21, Pl. I, but it can not be regarded as a promising source of fuel. The same may be said of a small field above Heppner, in Morrow County, as described by W. C. Mendenhall in this bulletin.

EASTERN FIELDS.

The present volume does not contain the results of geologic work in the eastern coal fields, as provision has been made for the publication of these results elsewhere. Work of this character was in progress in two States only in 1907, namely, Illinois and Pennsylvania.

Illinois.—Work on the coal fields of Illinois was carried on jointly by the State and Federal surveys, with the understanding that each organization should have access to the results obtained by the field parties of the other. Under this arrangement certain areas have been studied and mapped. Reports of this work will appear in the Yearbook of the State Survey, and consequently are omitted from this bulletin.

Pennsylvania.—In 1907 considerable new work was done in the bituminous coal fields of Pennsylvania under the direction of George H. Ashley. This work was done by the Federal Survey, in cooperation with the State organization. The close detailed work in this State is of the utmost economic importance, but as brief accounts are to appear in a progress publication by the State, they will be omitted here.

Virginia.—No regular geologic work was done in Virginia, but a brief examination of the Black Mountain coal field was made by Cassius A. Fisher. This work was not done with sufficient care to enable the section to be tied to the top of the Lee conglomerate, which is the key rock of the region, but the section seemed to be of sufficient importance to warrant publication.

COAL.

In attempting a general investigation of the western coal fields close attention was given to the study of the coal itself, as to its physical, chemical, and commercial properties. Such a study can be more profitably undertaken in these States than in the older and better-known fields of the East, for the reason that many single fields contain several grades of coal, and in the Rocky Mountain province as a whole all grades from lignite to anthracite are represented.

The study of the various kinds of coal has not progressed far enough to say what shall be the exact limits assigned to these grades, but the grades themselves are fairly well established and have been definitely adopted by the Geological Survey for use in its publications. They are as follows: (1) Anthracite, (2) semianthracite, (3) semibituminous, (4) bituminous, (5) subbituminous, (6) lignite. The first three are not common in the western fields, and their definition will not be attempted at the present time, further than to say that the common trade distinctions will be followed. The distinction between bituminous, subbituminous, and lignite is much more important in the West, and provisional definitions are given as follows:

Lignite: Brown, woody, or earthy coals which slack quickly on exposure to the atmosphere. Their moisture content is usually over 30 per cent, and their heating value is generally less than 8,000 B. t. u.

Subbituminous coal: Intermediate in quality between lignite and bituminous coal. It is generally glossy black, is relatively free from joints, and slacks readily on exposure to the atmosphere. Coal of this grade is usually called "black lignite," but it is not woody in appearance, and more nearly resembles bituminous coal than lignite. Its moisture content is usually over 10 per cent, and its heating value ranges from 8,000 to 11,000 B. t. u.

Bituminous coal: Bituminous coal hardly needs description, since it is the coal with which most persons are familiar. In a commercial way it is distinguished from subbituminous coal by its ability to withstand the weather.

CHEMICAL WORK.

For the purpose of classifying the coals and determining the values of the coal land, a great many samples were collected for analysis. In order to make comparisons with the analyses of coals from different fields and different regions and provinces, the sampling was done according to a uniform method, as follows:

1. Select a fresh face of unweathered coal at the point where the sample is to be obtained, and clean it of all powder stains and other impurities.

2. Spread a piece of oilcloth or rubber cloth upon the floor so as to catch the particles of coal as they are cut and to keep out impurities and excessive moisture where the floor is wet. Such a cloth should be about $1\frac{1}{2}$ by 2 yards in size and spread so as to catch all the material composing the sample.

3. Cut a channel perpendicularly across the face of the coal bed from roof to floor, with the exceptions noted in paragraph 4, and of such a size as to yield at least 5 pounds of coal per foot of thickness of coal bed—that is, 5 pounds for a bed 1 foot thick, 10 pounds for a bed 2 feet thick, 20 pounds for a bed 4 feet thick, etc.

4. All material encountered in such a cut should be included in the sample, except partings or binders more than three-eighths inch in thickness and lenses or concretions of sulphur or other impurities greater than 2 inches in maximum diameter and one-half inch in thickness.

5. If the sample is wet it should be taken out of the mine and dried until all sensible moisture has been driven off.

6. If the coal is not visibly moist, it should be pulverized and quartered down inside the mine to avoid changes in moisture, which take place rapidly when fine coal is exposed to different atmospheric conditions. The coal should be pulverized until it will pass through a sieve with $\frac{1}{2}$ -inch mesh, and then, after thorough mixing, it should be divided into quarters and opposite quarters rejected. The operation of mixing and quartering should be repeated until a sample of the desired size is obtained. When the work has been properly done a quart sample is sufficient to send for chemical analysis. This should be sealed in either a glass jar or a screw-top can with adhesive tape over the joint, and sent to the chemical laboratory for analysis.

All chemical analyses were made at the laboratory of the fuel-testing plant of the Geological Survey, located at the Carnegie Technical Schools, Pittsburg, Pa. The analytical work was under the immediate charge of F. M. Stanton, who conducted the laboratory under the general direction of N. W. Lord, of the Ohio State University, Columbus, Ohio. Professor Lord's high standing as a coal chemist is sufficient guaranty of the accuracy of the analyses contained in this bulletin.

When a sample reached the chemical laboratory, it was given a serial number by which it could be recognized, and was pulverized and quartered down in the ordinary way for analysis. As the samples were taken in the mines and not allowed to dry before they were pulverized and quartered down, it is generally true that they contained more moisture than the commercial coal. Before attempting to analyze a sample it was deemed desirable to eliminate some of this excess moisture, and for this purpose the following apparatus was used:^a

In order to make determinations of the loosely held moisture more uniform and definite, a special drying oven has been designed and introduced into the laboratory. In this oven samples of several pounds weight can be dried in a gentle current of air raised from 10° to 20° above the temperature of the laboratory. In this way the coal is air dried in an atmosphere with a very low dew-point and not subject to large percentage variations, and the results obtained are considerably more concordant.

The sample was then weighed, and the loss in weight is given as the "air-drying loss." The results of the analysis of this sample are the best for ordinary purposes, and are generally spoken of as the analysis of the air-dried sample. From this set of figures the analysis is easily recalculated back to the theoretical condition of the sample as

^a Bull. U. S. Geol. Survey No. 290, 1906, pp. 29-30.

received, and this result is also given in the tables of analyses. In every case the two analyses are presented as a matter of convenience to the general reader, who may use either the analysis that represents coal as it came from the mine, with more or less mine water in its pores, or the analysis of the sample dried under nearly ordinary atmospheric conditions. It is believed that the latter more nearly represents commercial coal than the former, and also that it is more nearly comparable to analyses of samples collected in the ordinary way from stock piles or cars of coal and shipped to a laboratory in canvas sacks.

The heating power of the coal sample was determined by burning a small briquet in a Mahler bomb calorimeter and noting the amount of heat given off during the process. It is expressed in both calories and British thermal units (B. t. u.).^a The calories may be converted into British thermal units by multiplying by 1.8.

A proximate analysis and a calorimetric determination were made on each sample sent to the chemical laboratory, and in special cases ultimate analyses were made in addition to those specified above. The comparative value of proximate and ultimate analyses is an extremely interesting subject, and it is to be hoped that the present work will go a long way toward showing the inadequacy and misleading character of the former and the great value of the latter, not alone for comparative purposes, but also as a base for economic calculations.

Up to the beginning of the fuel-testing work by the Geological Survey at St. Louis in 1904 very few ultimate analyses of coal had been made in this country. Fortunately Professor Lord, who had charge of all chemical work for the fuel-testing plant, had already learned the unreliable character of proximate analyses and had determined, wherever practicable, to make ultimate analyses. Lack of funds alone prevented him from making ultimate analyses of all samples received, but even with the limited means at his command several hundred such analyses of coal have been made. Time and space forbid a full discussion of this subject, but some of the shortcomings of the proximate analysis are the variable amount of volatile matter, dependent on the rapidity with which it is driven off (amounting in some samples to 20 per cent), and the fact that in many analyses of anthracite and other high-grade coal the total carbon in the ultimate is less than the so-called fixed carbon in the proximate. These points are discussed more fully in Bulletin 323.

The final paper in this volume is a bibliography by Willis T. Lee and John M. Nickles of the reports of the United States Geological Survey, exclusive of those on Alaska, that deal directly or indirectly with the subject of coal.

^a Calory: Amount of heat required to raise 1 kilogram of water 1° C. British thermal unit: Amount of heat required to raise 1 pound of water 1° F.

THE SENTINEL BUTTE LIGNITE FIELD, NORTH DAKOTA AND MONTANA.

By A. G. LEONARD and CARL D. SMITH.

INTRODUCTION.

As shown by the key map (fig. 1), the Sentinel Butte field is a small area near the center of the Fort Union region of coal and lignite bearing rocks of Tertiary age, which cover a considerable area in the northern part of Wyoming, the eastern quarter of Montana, the western

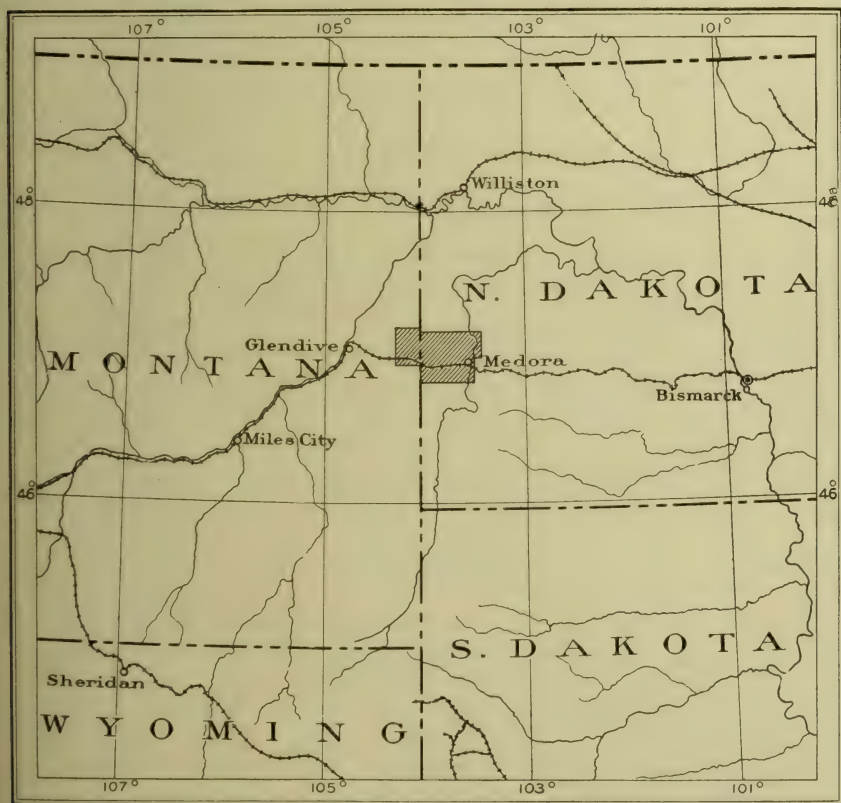


FIG. 1.—Index map showing location of the Sentinel Butte lignite field, North Dakota and Montana.

half of North Dakota, and the northwest corner of South Dakota. The field examined in 1907 comprises approximately 25 townships—19 in Billings County, N. Dak., and 6 in Dawson County, Mont., on either side of the Northern Pacific Railway.

The geologic investigations were undertaken primarily for the purpose of classifying the public lands with special regard to lignite. In order to do this, the character, depth, and horizontal distribution of the beds of lignite were studied in detail, and outcrops and exposures were located with reference to established land corners.

This region has been investigated in a general way by a number of geologists, notably by Wood, Wilder, and Leonard, of the North Dakota Geological Survey, and by Storrs, of the Federal Survey. In the field work the writers were ably assisted by Fred H. Kay and W. H. Clark, and in the office Mr. Kay compiled the accompanying map from the original township plats used in the field.

ACCESSIBILITY.

Much of the lignite of this field is accessible without great difficulty. The area is traversed from east to west by the Northern Pacific Railway, which is not more than 15 or 18 miles from any part of it. Many of the lignite beds that outcrop along Little Missouri River could be readily reached by a branch line along the valley of that stream, and the same is true of the lignite on Beaver Creek. Other parts of the field would be accessible to railways built across the upland plains.

DRAINAGE AND WATER RESOURCES.

With the exception of an area drained by a few streams heading in the westernmost tier of townships and flowing northwestward into Yellowstone River, the field lies in the drainage basin of Little Missouri River, which flows northward across the eastern part and contains running water throughout the year. Beaver Creek, also a perennial stream, runs northeastward across the western part of the field and joins Little Missouri River some distance north of the area mapped. All the other streams are intermittent, but some of them contain water in pools during dry seasons.

TOPOGRAPHY.

Broadly characterized, the region is a rolling plain which is minutely dissected near the larger streams, the result being so-called badlands. Three important eastward-flowing streams—Andrews, Knutson, and Wannigan creeks—empty into Little Missouri River. All these streams have cut deep valleys in the plain and exposed to view the strata which underlie its surface. The badlands are confined chiefly to a strip of country bordering Little Missouri River and extending about an equal distance on either side. This very rough area, with its bare clay slopes, sharp divides, and rain-carved buttes, occupies a belt 15 to 20 miles wide. The entire width of the badlands, however, is not included in the district studied, as they extend from

north to south along its eastern border only. On the west they pass into the rolling plain which stretches to the badlands of Yellowstone River.

Conspicuous features of the valley of the Little Missouri are the broad flats which occur at intervals on both sides at an elevation of 240 feet above the river. They have a width of 1 or 2 miles and overlooking them are bluffs rising rather abruptly 160 to 200 feet higher, or about 420 feet above the river. These flats were probably formed when the land was considerably lower than at present, and the river, having reached base-level, meandered back and forth over a flood plain 4 or 5 miles wide. The surface was then elevated, and the river gained a new erosive power and has since cut its inner gorge to a depth of about 240 feet below its old valley bottom, represented by the flats. The valley as a whole has a depth of 420 to 440 feet below the upland plain in which it has been eroded. The altitude of this upland plain ranges from 2,700 to 2,800 feet, and rising above it are three prominent buttes—Sentinel, Square, and Camels Hump—with great numbers of lesser buttes. Sentinel Butte has a height of 3,350 feet above sea level, and its flat summit forms a landmark visible for 20 to 30 miles in all directions.

The gently rolling plain is itself the product of long-continued erosion, which has doubtless been going on ever since Oligocene time, resulting in the removal of 800 to 1,000 feet of strata from this region. Remnants of these eroded beds are found in the buttes just mentioned, Sentinel Butte rising 650 feet above the plain at its base and containing on its summit the evidence of a still more recent formation that has almost entirely disappeared. Sentinel and Square buttes are capped with heavy ledges of sandstone, about 100 feet thick, which have protected them from erosion and given them their flat summits. In the vicinity of Sentinel Butte there are a large number of small buttes that rise from 150 to 175 feet above the surrounding surface to a fairly uniform height and are capped by a thick layer of baked and fused clay. This red clay, which has protected the buttes from erosion, was formed by the burning of the 21-foot bed of lignite that is present in the base of Sentinel Butte.

In places the change is abrupt from the upland plain to the badland belt along the river. To one looking out over the badlands from some commanding point the scene presents an indescribable waste of steep-sided ridges, bluffs, buttes, domes, and pinnacles carved out of the soft clays and sands of the Fort Union formation. The bare slopes which are so conspicuous a feature of the region everywhere show the marks of the last shower, being grooved with countless tiny channels formed by the rivulets of water which poured down their sides. At one or more horizons bands of red, burnt clay may be readily traced with the eye for many miles in the bluffs and ridges. These beds of clay,

rendered hard and resistant by the heat of the burning lignite, have been an important factor in the formation of the picturesque badlands.

GEOLOGY.

STRATIGRAPHY.

FORT UNION FORMATION.

Practically all of the strata in the area under discussion belong to the Fort Union formation (early Eocene). In common with the rocks of the adjoining regions they have in the past been generally referred to the Laramie, but according to F. H. Knowlton, who spent some time in this field in the summer of 1907 making collections of plant remains, their Fort Union age is unmistakable.

There is a very noticeable difference between the lower Fort Union beds, which outcrop in the bluffs bordering Little Missouri River, and the upper beds, occurring in the tops of the higher ridges, divides, and buttes, usually back some distance from the river. The lower member is composed of buff and light ash-gray clays and sands in alternate layers. The upper member is formed of strata considerably darker in appearance, mostly dark gray, with many brown, ferruginous, sandy nodules and concretions. The contrast between these members is so well marked and their contact so clearly defined that it can be readily distinguished at a distance and traced without difficulty wherever it is exposed. Over most of the eastern half of the field a thick bed of lignite or a layer of red clay formed by the burning of the lignite occurs just at the contact of the upper and lower members. But even where the coal or burnt-clay bed is wanting, the line of separation is readily discernible. The lignite beds appear equally in both divisions, though there are perhaps more in the lower. Of the workable lignite beds shown in the generalized section (Pl. II) the lower five are in the lower member, the next separates the two members, and the other three beds are in the upper division.

The character of the Fort Union formation is well shown by the following sections:

Section in river bluff about one-fourth mile below the crossing at Short's ranch, in the SE. $\frac{1}{4}$ sec. 1, T. 142 N., R. 102 W.

	Ft. in.
Clay and sand, buff and gray, on which rest the somber beds of the upper member.....	17
Lignite.....	1 6
Sand, fine grained; contains some clay, buff and gray.....	77
Lignite.....	1
Clay, gray and yellow.....	16
Lignite, impure, containing two thin clay seams.....	1
Clay and sand.....	17
Clay, brown.....	1
Clay, gray.....	7 6
Lignite and some brown clay.....	6
Clay, blue and yellow.....	7

	Ft.	in.
Clay, brown and carbonaceous.....		8
Sand, with some clay.....	6	
Clay.....	4	
Lignite.....		8
Clay, gray.....	1	6
Lignite.....	1	
Clay, gray and yellow.....	3	
Sand, gray, fine.....	8	
Lignite.....	2	6
Clay, blue.....	7	6
Lignite.....	1	8
Clay, blue, plastic.....	5	6
Lignite, with 6-inch clay parting 3 inches above bottom....	2	6
Clay, blue, plastic.....	3	6
Lignite.....		5
Clay, blue, plastic.....	3	
Lignite.....		9
Clay, blue.....	3	
Sand, yellow and gray, fine grained and laminated.....	4	
Lignite.....		1
Clay, gray.....		6
Lignite, with 1-inch parting.....		9
Clay, bluish gray.....	4	
Clay, gray and brown, with a thin streak of lignite.....		4
Sand, yellow and gray.....	3	
Clay, light gray, growing sandy above.....	1	4
Clay, brown.....		4
Lignite.....	1	6
Clay, light gray, with thin streak of lignite.....	1	1
Sand, gray.....	3	
Clay, blue and yellow.....		8
Sand, yellow and gray.....	4	
Clay, sandy and finely laminated.....	1	4
Clay, blue.....		3
Lignite.....		3
Clay.....		7
Lignite.....		6
Sand, growing clayey above.....	2	
Clay, bluish gray, with thin streak of lignite.....	6	
Sand, gray.....	5	
Lignite.....	1	2
Clay, sandy, yellow.....	6	
Lignite, with some brown clay.....		4
Clay, sandy and laminated toward top.....	14	
Lignite.....		2
Clay, gray.....	3	6
Lignite and brown clay.....		1
Sand, gray, fine.....	1	6
Clay, gray.....	2	
Clay, brown, with 2 to 4 inches of lignite at base.....		8
Clay, light gray.....	2	8
Sand, gray, fine grained, with hard ledge of rock near top; exposed above river.....		14

It will be noted that although there are twenty beds of lignite in the foregoing section, none of them is workable, the thickest being 30 inches. But the thick lignite bed which outcrops less than 2 miles above and below the point where the section was measured can not here be far below river level.

The following section was measured in the NE. $\frac{1}{4}$ sec. 4, T. 142 N., R. 101 W., 3 miles east of the one just given, and lies wholly in the upper division of the Fort Union, its base resting on top of the lower member:

Section $3\frac{1}{2}$ miles east of Short's ranch, in the NE. $\frac{1}{4}$ sec. 4, T. 142 N., R. 101 W.

	Ft.	in.
Sand and clay in alternating layers, more argillaceous at the base.	80	
Lignite band, thin.		
Clay, sandy.....	10	
Clay, bituminous.....	2	
Clay, sandy.....	10	
Powdery material, probably weathered, shaly lignite.		
Clay, gray, forming when wet a sticky mud, sandy near middle..	25	
Lignite in two beds, the upper 1 foot and the lower $1\frac{1}{2}$ feet, separated by 4 inches of brown shale.....	2	10
Clay, gray, with hard, concretion-like masses of same color....	55	
Lignite.....	2	
Clay, gray, sandy.....	10	
Lignite.....	1	
Clay, gray, sandy, more clayey above and below.....	50	
Lignite.....	3	6
Sand and sandy clay, gray, rather coarse sand near center, fine grained at top and bottom, with yellow bands.....	55	
Lignite.....	1	
Sand, clayey, bluish gray, contains irregular ironstone bands, rather coarse sand at base, but grows gradually finer till at top it is a clay.....	40	
Lignite, poor	} Bed F, Sentinel Butte group.....	{ 1 3
Clay, gray ..		
Lignite, poor		
		3
	358	7

The beds of the upper division of the Fort Union are found in Sentinel Butte, and the following section was measured there:

Section at Sentinel Butte.

	Ft.	in.
Clay, calcareous.....	10	
Limestone, alternating with calcareous clay; the limestone is very compact and fine grained, brittle, siliceous, and gray and white in color, weathering into very thin laminæ; contains fish remains.....	5	
Clay, gray, very calcareous, weathering to greenish.....	25	
Sandstone, gray, hard.....	80	
Clay, gray and yellow, sandy.....	30	
Clay, brown, with thin seam of lignite.....	1	6

	Ft.	in.
Clay, gray and yellow, sandy.....	53	
Lignite.....		6
Sand, fine grained, clayey.....	12	
Clay, brown and gray, containing many selenite crystals.....	4	
Sandstone, soft, fine-grained.....	1	
Lignite.....		1 6
Clay, brown and carbonaceous.....	1	
Clay, bluish gray.....	10	
Sand, gray, cemented in places into a soft sandstone.....	12	
Clay and sand, not well exposed.....	55	
Lignite.....		6
Clay, gray, sandy.....	37	
Clay, gray, with no sand.....	2	
Lignite.....		6
Clay, brown at the top, sandy.....	5	
Sand, gray, fine.....	4	
Clay, gray, sandy, containing nodules.....	15	
Sand, finely laminated.....	4	
Clay, gray, sandy, with ferruginous bands.....	8	
Clay, brown, sandy.....	1	
Clay, gray.....	5	
Clay, gray, sandy, containing abundant siliceous and ferruginous nodules, arranged mostly in bands at certain horizons; these hard nodules project from surface of softer clays, and cap small clay columns.....	25	
Sand and clay not well exposed.....	25	
Lignite.....		21 2
Unexposed to level of railroad at Sentinel Butte station.....	190	
	650	2

The Fort Union formation has a thickness in this region, as measured on its outcrop, of 900 feet. If to this be added 820 feet of lignite-bearing rocks, which are probably to be referred to the Fort Union, penetrated by the Medora well below the lowest lignite outcropping in the field, the total thickness is 1,720 feet.

OLIGOCENE ROCKS.

Overlying the heavy sandstone which forms the summit of Sentinel Butte and constitutes the topmost member of the Fort Union formation, there are about 40 feet of calcareous clay and limestone, as shown in the Sentinel Butte section. These beds are merely the remains of a formation which doubtless at one time covered a large area in this region. Strata which have yielded Oligocene vertebrates, and which occupy a similar horizon immediately over the massive sandstones at the top of the Fort Union, occur in Chalk Butte, 70 miles farther southeast. Other similar buttes in northwestern South Dakota and southeastern Montana have likewise been referred to the Oligocene.

STRUCTURE.

Little can be said of the structure of the small area here discussed except that the strata have a low dip—20 feet to the mile—toward the northeast. However, work in adjoining territory has proved that the structure of the field is the result of an upward fold of the rocks, or anticline, whose axis trends northwest and southeast and is located 25 miles to the southwest. This anticline is well exposed at the mouth of Cedar Creek, Montana, where it is crossed by Yellowstone River. Here 300 feet of Pierre shale, of Cretaceous age, is brought to the surface, and the overlying rocks, including the Fort Union, dip away from it, steeply toward the southwest and gently toward the northeast. The gentle dip continues, however, to the northeast corner of the field represented on the accompanying map, where the rocks are horizontal. What is probably an extension of this disturbance is marked by an exposure of Pierre shale on Little Beaver Creek, in Bowman County, N. Dak.^a

Throughout the field the dip is so slight that it can be detected only by tracing certain well-marked horizons and by noting their change of altitude from point to point. For example, the elevation of the contact of the buff and somber-colored members in the base of Sentinel Butte is 2,850 feet above sea level, but in the northeast corner of the area the same contact is at 2,430 feet. Further evidence that the rocks are tilted is the fact that artesian water has been obtained at Medora. A well was sunk here by the Northern Pacific Railway Company to a depth of 940 feet, where a water-bearing sandstone was reached. To judge from the thickness of the Fort Union section at Glendive, Mont., it is believed that this sandstone lies near the base of the formation and that it is exposed at a higher level far to the southwest along the flank of the anticline mentioned above.

THE LIGNITE.

GENERAL STATEMENT.

By referring to the columnar section on the map accompanying this report (Pl. II), it will be noted that workable beds of lignite occur at nine different horizons in the 900 feet of strata exposed in the field. A great many other beds 1 foot or less in thickness can be seen in almost any well-exposed rock section, but no attempt has been made to note them. The workable lignite beds, with one exception, are for convenience of description divided into groups, the lower being termed the Medora and the upper the Sentinel Butte group. The lowest lignite exposed in the field is called the Harmon bed; it outcrops in the east bank of Little Missouri River a short

^a Leonard, A. G., Bull. U. S. Geol. Survey No. 316, 1907, p. 196.

distance above the Harmon ranch, at the southern boundary of the field. The two uppermost members of the Sentinel Butte group are so meager in distribution that their outcrops have not been mapped. The record of a drill hole sunk at Medora shows that at least 800 feet of lignite-bearing rocks lie below the Harmon bed.

VARIABILITY.

Heretofore the lignite beds of this general region have been described as lenticular in form and impossible of correlation for distances exceeding 2 or 3 miles. It is true that the lignite is variable in thickness and horizontal extent, but some of the more important beds have been traced continuously for 24 miles and have been correlated with much certainty for greater distances. So far as this area is concerned, there is a more or less definite law controlling the disappearance of the beds. It has been observed that the two lower members of the Sentinel Butte group become thin and pinch out toward the northwest. Some of the members of the Medora group follow the same rule, but whether this law has a general application can be ascertained only by further detailed work in the surrounding territory. The clinker zone left by the burning of the two lower members of the Sentinel Butte group bears conclusive evidence that they formerly occupied the entire southeast corner of the field and that they extended still farther to the east and southeast, covering a large territory beyond the limits of last season's investigations.

CLINKER.

A noticeable feature which has had a great influence on the topography of the field is the clinker or baked and partially fused sands and clays, due to the burning of the coal beds. The prevailing color of this material is red, but various shades of yellow and green were also observed. The more completely fused portions are usually dark red to black. At places these clinker zones are 100 feet thick, but it is not likely that so great a thickness has resulted from the burning of a single bed. The distance back from the outcrop of a bed to which burning may take place depends on the amount of cover. Wherever the cover is great enough combustion is soon smothered by the weight of the overlying material. It is impossible to give exact figures in this connection, as no prospecting or mining has ever been done where a lignite bed is rimmed by clinker. In prospecting for lignite along an outcrop which has been burned it will be noted that the base of the clinker, which is usually well marked, is on a level with the base of the bed of lignite.

It may be well to say here that, as a general rule, the lignite beds that have been burned most extensively are the thicker and purer

beds, although here and there dirty beds burn, making considerable clinker. Moreover, the burning of thicker beds causes more complete fusion of the overlying material than the burning of thin or impure beds.

Little is known as to the manner in which the lignite may have been ignited, except in a few places where it is known to have been set on fire by human agencies and is still burning. Other explanations as to the origin of the fire are more or less theoretical and attribute it to lightning, to prairie fires, and to spontaneous ignition. All of these causes have doubtless been instrumental, each becoming active under favorable conditions.

EXPLANATION OF MAP.

The outcrops of seven different beds of lignite have been mapped in various parts of the field, and in order to distinguish these beds, a columnar section showing their relative positions has been placed on the map, with a letter opposite each, corresponding to the same letter written along its line of exposure on the map (Pl. II).

DETAILED DESCRIPTION OF LIGNITE BEDS.

A few representative detailed sections, beginning with the lowest lignite exposed in the area covered by this report, are given in the following pages, in the order of their occurrence.

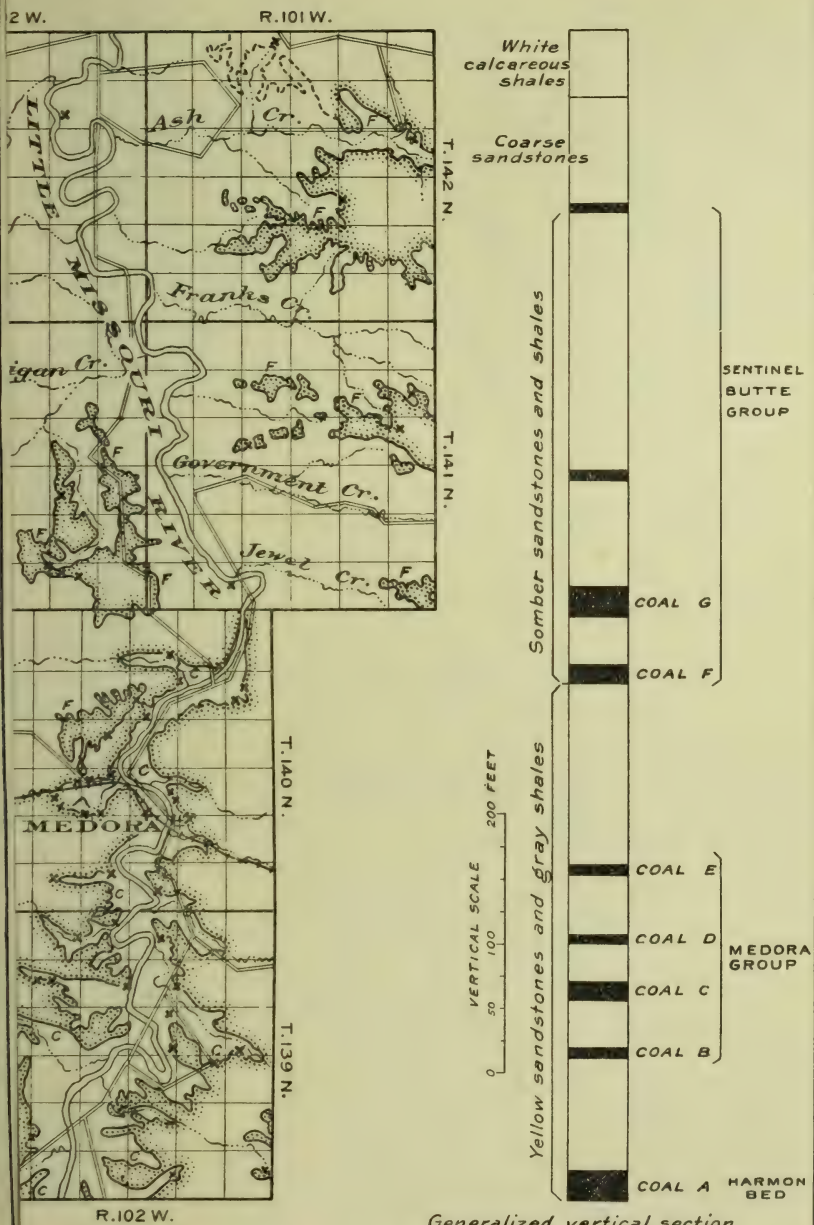
HARMON LIGNITE BED.

The Harmon lignite, A in the columnar section, is the lowest bed of consequence within the limits of the area investigated. It is partially exposed in the east bank of Little Missouri River, one-half mile south of the south boundary of the Sentinel Butte field. Here the section is as follows:

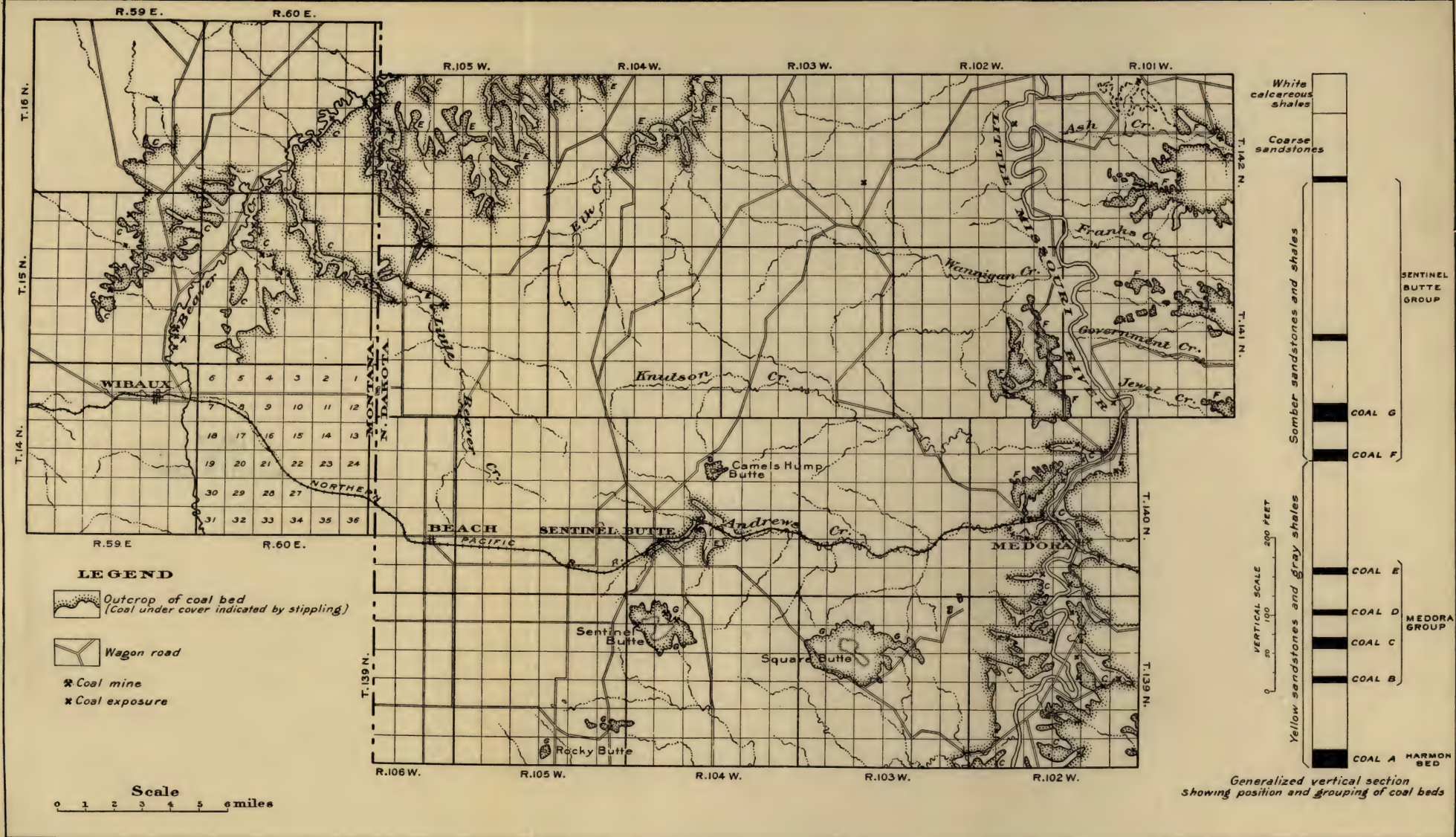
Section of Harmon lignite one-half mile south of south boundary of Sentinel Butte field, on Little Missouri River.

	Ft.	in.
Clay, sandy.		
Lignite.....		4
Clay, sandy.....		5
Lignite (with four thin shale partings).....	4	2
Lignite.....	7	6
Lignite (with three thin shale partings).....	1	
Lignite (base concealed by water).....	2	6
Total lignite.....	15	6

North of this exposure the bed dips beneath the level of the river and does not appear again in the eastern part of the field. Lignite, which is without doubt the Harmon bed, was penetrated in a well sunk by the Northern Pacific Railway Company at Medora. The



Generalized vertical section showing position and grouping of coal beds



MAP OF THE SENTINEL BUTTE LIGNITE FIELD, NORTH DAKOTA AND MONTANA.

By A. G. Leonard, C. D. Smith, and F. H. Kay.

well record shows it to be 23 feet thick and about 120 feet below the surface.

A lignite occupying the same position in the section as the Harmon bed outcrops in the east bank of Beaver Creek, 2 miles north of Wibaux, Mont. It ranges from 8 feet 6 inches to 9 feet 3 inches in thickness and is mined to supply local trade. Northward from this point the lignite dips below the level of the creek, but to the south it rises slightly above the creek level as far as observed. In T. 15 N., R. 59 E., in Montana, the Harmon lignite outcrops near the head of Box Elder Creek, a tributary of Yellowstone River, but its outcrop has not been mapped. In T. 16 N., R. 59 E., this bed outcrops near the head of Cottonwood Creek, but owing to the fact that it has been burned extensively no complete section of the bed could be measured. A partial exposure, where only the top portion could be seen, measures 8 to 10 feet. The upper part of this bed, or a bed occupying a similar position in the section, was noted in the south bank of Beaver Creek, a short distance north of the field.

MEDORA GROUP OF LIGNITE BEDS.

The Medora group of lignite beds, so named because of the occurrence and exposure of its members in the bluffs of Little Missouri River at and near Medora, N. Dak., occupies a position from 150 to 290 feet above the Harmon bed. The group comprises four beds, designated in the vertical section on the map by the letters B, C, D, and E. Along Little Missouri River the outcrop of only one member of the group, bed C, has been mapped. This bed, the second above the base of the group, is more persistent and thicker than the others, and has been mined for local use at a number of places, notably near Medora. But as the three lower members lie within a vertical range of 60 to 80 feet, the mapped outcrop of the second above the base, bed C, marks approximately in steep slopes and bluffs the outcrop of the other two. The outcrop of the uppermost member of the group has been mapped wherever it shows workable thickness.

At the southern boundary of T. 139 N., R. 102 W., the lowest member of the Medora group, bed B, has an elevation of 100 feet above the level of Little Missouri River, and in conformity with the general dip of the inclosing rocks the various members of the group dip toward the northeast and disappear below the level of the river near the north line of T. 140 N., R. 102 W.

All the members of the group are exposed in the northern and western parts of the field, notably on Elk, Beaver, Little Beaver, and Dry creeks.

Some detailed sections of members of this group follow:

*Section of bluff on west bank of Little Missouri River 500 feet south of south line of
T. 139 N., R. 102 W.*

	Ft.	in.
Sandstone, yellowish white, soft, and gray sandy clay	145	
{ Lignite	6	6
{ Shale, brown	1	7
Bed C ^a { Lignite		6
{ Shale, brown and gray	1	7
{ Lignite, upper 10 inches dirty	3	
Clay and sandstone	40	
{ Lignite, soft and powdery	1	2
Bed B { Clay, gray	2	3
{ Lignite, weathered	2	10
Clay, buff	17	6
Shale, carbonaceous	4	2
Clay, yellow, sandy	27	6
Lignite	1	
Clay, light colored	17	
Shale, carbonaceous	1	1
Clay	9	
Clinker and concealed to river level	20	
Total lignite	15	

*Section of two lower members of Medora group near Custer Trail ranch, in the SE. $\frac{1}{4}$
sec. 15, T. 139 N., R. 102 W.*

	Ft.	in.
Shale, carbonaceous		
{ Lignite	1	6
{ Shale		6-11
Bed C { Lignite	6	6
{ Clay, brown	1	
{ Lignite	5	10
Clay, sandy	40	
Bed B: Lignite	6	6
Clay, sandy	66	6
Clay, carbonaceous	3	6
Clay, sandy, to level of river	10	
Total lignite	20	4

Section at Medora, in the NW. $\frac{1}{4}$ sec. 26, T. 140 N., R. 102 W.

	Ft.	in.
Shale, brown		
Bed D: Lignite	4	6
Shale, clay, and sandstone	30	
{ Lignite	8	2
Bed C { Clay, white		3
{ Lignite		11
Clay, sandy, to river level	40	
Total lignite	13	7

^a 125 feet above river level.

Section near mouth of Knutson Creek, in the NW. $\frac{1}{4}$ sec. 11, T. 140 N., R. 102 W.

	Ft.	in.
Bed D: Lignite.....	5	6
Clay, sandy.....	25	
Bed C: Lignite.....	9	
Concealed to river level.....	20	
Total lignite.....	14	6

A bed of lignite 5 feet thick exposed in the south bank of Little Missouri River, in the NE. $\frac{1}{4}$ sec. 32, T. 141 N., R. 101 W., probably represents the second member below the top of the Medora group, the other members being present below the level of the river.

Bed E shows workable thickness, and its outcrop has been mapped along the banks of Andrews Creek, in T. 140 N., R. 104 W., near the town of Sentinel Butte. Two sections follow:

Section of bed E in the NE. $\frac{1}{4}$ SW: $\frac{1}{4}$ sec. 21, T. 140 N., R. 104 W.

	Ft.	in.
Sandstone, soft, yellowish.....	20	
Lignite.....	5	2
Clay.....	5	6
Lignite.....	1	
Clay.....	5	6
Lignite.....	1	6
Total lignite.....	7	8

Section of bed E in the SE. $\frac{1}{4}$ sec. 22, T. 140 N., R. 104 W.

	Ft.	in.
Clay, blue, sandy.....	6	
Lignite.....	1	6
Clay, bituminous.....		4
Lignite.....	5	
Total lignite.....	6	6

An exposure of bed C in sec. 11, T. 142 N., R. 102 W., on the east side of Little Missouri River, shows the following section:

Section of bed C in east bank of Little Missouri River, in sec. 11, T. 142 N., R. 102 W.

	Ft.	in.
Clay, sandy.....		
Lignite.....	1	
Clay.....	5	6
Lignite.....	3	
Clay, sandy.....	6	
Lignite.....	6	
Clay, sandy.....	3	6
Lignite.....	6	
Clay.....		
Total lignite.....	16	

Farther north, on the west side of the river, the following section is exposed:

Section of bed C on west bank of Little Missouri River near Bryan's ranch, about 1 mile north of north line of T. 142 N., R. 102 W.

		Ft.	in.
Bed C	{ Lignite.....	2	10
	{ Clay.....		10
	{ Lignite.....	3	4
	{ Clay.....		10
	{ Lignite.....	7	7
Clay, sandy, to river level.			
Total lignite.....		13	9

An exposure of this bed near the mouth of Roosevelt Creek, a short distance north of the foregoing section, shows the same number of benches of lignite, all slightly thinner.

In sec. 34, T. 142 N., R. 103 W., on Wannigan Creek, near Bird's ranch, an exposure of lignite is 3 feet 9 inches thick. This is probably bed E.

In T. 142 N., R. 104 W., bed E is exposed in the banks of Elk Creek, near Wilson's ranch. In sec. 16 this bed measures 4 feet 4 inches. Farther down the creek the section is as follows:

Section of bed E in the SW. $\frac{1}{4}$ sec. 1, T. 142 N., R. 104 W.

	Ft.	in.
Lignite.....	8	
Clay.....	6	
Lignite.....	2	6
Total lignite.....	3	2

In T. 142 N., R. 105 W., bed E is of workable thickness in a number of places and has been mapped entirely across the township. Toward the northwest it becomes thin, but to the east it is thicker, as shown by the section near the northeast corner of the township:

Section of lignite beds near the northeast corner of T. 142 N., R. 105 W.

	Ft.	in.
Clays, dark gray, with irregular black calcareous bands.....	100	
Sandstone, yellowish, and gray clay.....	40	
Lignite.....	1	
Clay, gray, and yellow sandstone alternating.....	30	
Lignite.....	3	6
Clay, gray, and yellow sandstone alternating.....	50	
Lignite.....	1	4
Sandstone and clay alternating.....	20	
Lignite.....	1	2
Sandstone and clay alternating.....	15	
Bed E: Lignite.....	6	
Clay, blue-gray.....	6	6
Lignite.....	1	3

	Ft.	in.
Sandstone and clay alternating.....	47	
Bed D: Lignite.....	5	6
Sandstone and clay.....	10	
Lignite.....		4
Sandstone and clay alternating.....	20	
Bed C { Lignite.....	2	9
{ Clay, gray.....		11
{ Lignite.....	4	3
Sand and clay.....	35	
Bed B: Lignite.....	3	8
Clay, sandy.....	11	
Level of Beaver Creek.....		
Total lignite.....	30	9

On Little Beaver Creek, in T. 141 N., R. 105 W., beds C and E show workable thickness, but only a small portion of the outcrop of bed E has been followed out. Toward the south its outcrop is divided by a number of partings and is lost in the grass-covered prairies.

The outcrop of bed C disappears below the level of Little Beaver Creek about one-half mile east of the State line, where it is about 6 feet thick.

Two mines or strip pits have been opened on bed E, one in the NW. $\frac{1}{4}$ sec. 8 and the other in the NW. $\frac{1}{4}$ sec. 16. Sections of the lignite at these mines follow:

Section of bed E in the NW. $\frac{1}{4}$ sec. 8, T. 141 N., R. 105 W.

	Ft.	in.
Lignite.....	6	6
Clay, sandy.....	8	
Lignite.....	3	
Total lignite.....	9	6

Section of bed E in the NW. $\frac{1}{4}$ sec. 16, T. 141 N., R. 105 W.

	Ft.	in.
Lignite.....	2	2
Clay, white.....	6	
Lignite.....	5	
Clay, white.....	6	
Lignite.....	5	6
Total lignite.....	8	1

In T. 16 N., R. 60 E., Montana, and in the northwestern part of T. 142 N., R. 105 W., North Dakota, bed C is thin and unworkable. Toward the south its outcrop runs through T. 15 N., R. 60 E., rising gradually above the level of Beaver Creek. Its outcrop is nearly everywhere marked by a fringe of clinkered material, due to the burning of the bed. The outcrop was not mapped farther south than the northern part of T. 14 N., R. 60 E., though the clinker occurs in the prairies to the southern boundary of the field.

A number of lignite beds lower in the section than bed C of the Medora group are exposed along the east bank of Beaver Creek, in the southeastern part of T. 16 N., R. 60 E. In a bluff on the east bank of Beaver Creek, in the NE. $\frac{1}{4}$ sec. 27, the following section was measured. The three upper beds probably represent bed C, with partings greatly increased.

Section in the NE. $\frac{1}{4}$ sec. 27; T. 16 N., R. 60 E., Montana.

	Ft.	in.
Sandstone, soft, yellow-white.....	22	
Lignite.....	2	
Sandstone, soft, dark.....	5	6
Lignite.....	1	
Sand, clayey, gray.....	4	9
Lignite.....	3	6
Sandstone, soft, white.....	20	
Lignite.....	5	6
Sandstone, white, clayey.....	10	3
Lignite.....	4	
Clay, dark gray.....	30	
Lignite.....		5
Level of Beaver Creek.....		
Total lignite.....	16	5

An exposure of bed C in the NE. $\frac{1}{4}$ sec. 12, T. 15 N., R. 59 E., measures 12 feet, but the upper part of the bed contains many thin partings of clay. Northward from this point the bed becomes thin, as shown by a measurement in the southwest corner of T. 16 N., R. 60 E., where it is only 5 feet thick. Toward the southwest the bed rises gradually and appears in small isolated areas near the tops of the highest hills.

SENTINEL BUTTE GROUP OF LIGNITE BEDS.

The Sentinel Butte group of lignite beds is so named on account of its occurrence in Sentinel Butte. Although the distribution of its members is now restricted to small detached areas, hundreds of clinker-capped buttes at the horizon of the two lower members of the group, dotting almost the entire eastern half of the area surveyed, bear evidence of the fact that these members covered at some earlier time a much larger area than at present, and that they have been burned over nearly all of the area.

The lowest member of the group, bed F of the columnar section, has its greatest development in the eastern part of the field, where it is from 10 to 16 feet thick. It is found at the contact of the buff sandstone and gray shale with the somber-colored member above. This contact is well marked on account of the abrupt change in the color and character of the material, and can be readily followed throughout the district where it occurs.

The second member of the group, bed G, from 25 to 50 feet above the lowest member, shows to better advantage in the south-central part of the surveyed area, in the base of the higher buttes, where its outcrop is marked by a fringe of clinker. Both the lower members become thin and disappear toward the northwest. These beds have been so generally burned that few exposures showing their whole thickness can be found. Other members ranging from 100 to 250 feet above the base of the group are so limited in distribution in the region examined that they will not be considered further than to say that they occur in Sentinel, Flat Top, and Camels Hump buttes, and in a small area in the extreme northeastern part of the region. The maximum thickness of the members of this group and their positions in the geologic column are shown in the graphic section on the map (Pl. II). Some detailed sections of the two lower members of the group are given below.

A few exposures of parts of the two lower members of the Sentinel Butte group were noted in the southeast corner of the field, where small patches of somber-colored beds are underlain by them. The coal is about 350 feet above the level of Little Missouri River at the southern boundary of the field. The outcrop of the lignite is so concealed by a fringe of clinker that it is difficult to find the whole of the lower bed exposed, but it is about 17 feet thick, apparently without partings. These beds are unimportant here, as they are detached bodies of small extent.

Section of bed G in the northeast base of Sentinel Butte, in the SE. $\frac{1}{4}$ sec. 5, T. 139 N., R. 104 W.

Clay, sandy, somber colored.	Ft. in.
Lignite.....	14
Clay.....	3
Lignite.....	6 11
Clay.	
Total lignite.....	20 11

This bed has been mined here for local use. The same bed has been mined in the NE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 7, $1\frac{1}{4}$ miles west of this exposure, and is there 20 feet 11 inches thick. It has also been mined in the SW. $\frac{1}{4}$ sec. 5, but its whole thickness could not be seen.

A number of small areas underlain by the lower members of the Sentinel Butte group remain in the southeast corner of T. 139 N., R. 105 W. Near the center of sec. 25 of this township, lignite is mined for neighborhood use by stripping. A section follows:

Section near center of sec. 25, T. 139 N., R. 105 W.

Clay, white.	Ft. in.
Lignite, weathered.....	8
Clay.....	10
Lignite (base concealed).....	7
Total lignite exposed.....	15

The lower bench is partially concealed, but is reported to be 10 feet thick and to be underlain by clay. This bed also occurs in the base of Rocky Butte, in sec. 34, but is so concealed by clinker that no measurement of its thickness could be made. To judge from the thickness of clinker produced by its burning along the outcrop, however, it is in all probability workable.

In the base of Square Butte, in T. 139 N., R. 103 W., beds F and G are separated by 25 feet of sandy clay. Their outcrops have been so completely burned that the coal is exposed at only a few points. Bed G, exposed in the NE. $\frac{1}{4}$ sec. 9, T. 139 N., R. 103 W., is 15 feet thick without partings. Bed F is about 5 feet thick. A few small isolated buttes, underlain by these two members of the group, lie between Square Butte and Little Missouri River, but the presence of clinker prevented any measurements. Bed G occurs in the base of Camels Hump Butte, in secs. 9 and 10, T. 140 N., R. 104 W., as indicated by the fringe of clinker left by its burning, but no actual exposure could be seen.

In the southeastern part of T. 141 N., R. 102 W., bed F outcrops near the top of a plateau, 250 feet above the level of Little Missouri River. It thins out toward the north and is worthless. In the N. $\frac{1}{2}$ sec. 35 only the upper $6\frac{1}{2}$ feet of the bed could be seen.

In the northern part of T. 142 N., R. 101 W., bed F, the lowest member of the group, is divided and replaced by partings so that little of it remains. Here the upper members of the group are thin and dirty.

In the eastern part of T. 142 N., R. 102 W., and in T. 142 N., R. 103 W., bed G outcrops near the top of the higher divides in the badlands. It is 250 feet above the river level, ranges in thickness from 3 to 5 feet, and is scarcely accessible for mining operations.

A few isolated buttes of sufficient height to contain bed F are found in T. 141 N., R. 103 W., and in T. 142 N., R. 104 W., but the rocks are either barren or contain thin, unworkable beds of lignite.

In T. 141 N., R. 101 W., bed F, at the contact of the somber-colored beds and the lighter beds below, occurs in more or less isolated buttes on the divides between Franks Creek and Government Creek, at an elevation of about 250 to 300 feet above Little Missouri River. In the SW. $\frac{1}{4}$ sec. 5 a small butte is underlain by this bed, which is 11 feet 6 inches thick, with a 3-inch clay parting 6 inches from the bottom. In the NW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 12 an exposure of a part of the bed measures 16 feet. It is probably not much thicker. A part of the S. $\frac{1}{2}$ sec. 36 is underlain by this bed, but the presence of clinker prevented any measurements.

In secs. 8, 9, 10, 16, and 17, T. 140 N., R. 102 W., at an elevation of about 275 feet above Little Missouri River, an irregular plateau is underlain by bed F, the lowest member of the group. Its outcrop is usually concealed by clinker, and no satisfactory measurements of its thickness could be made.

Bed F occurs in T. 142 N., R. 101 W., at an elevation of about 250 feet above Little Missouri River. Its outcrop is extremely sinuous and is everywhere fringed by a rim of clinkered material. In the southeastern part of the township the lignite is so concealed that no measurements of its thickness could be made, but it is probably about as thick as it is in the next township south, or about 15 feet. North of Ash Creek partings develop in the bed, replacing and dividing it so that it is rendered unworkable. Some detailed sections of this bed follow:

Section of bed F in NE. $\frac{1}{4}$ sec. 4, T. 142 N., R. 101 W.

	Ft.	in.
Lignite.....	1	3
Clay.....		7
Lignite.....		3
Total lignite.....	4	3

Section of bed F near center of N. $\frac{1}{2}$ sec. 13, T. 142 N., R. 101 W.

	Ft.	in.
Lignite.....	2	7
Clay.....		7
Lignite.....	1	11
Clay.....	1	1
Lignite.....	1	5
Total lignite.....	5	11

Section of bed F near northeast corner sec. 15, T. 142 N., R. 101 W.

	Ft.	in.
Lignite.....	2	8
Clay.....		8
Lignite.....	4	2
Total lignite.....	6	10

CHARACTER AND USES OF THE LIGNITE.

The lignite is brown, tough, and woody in structure. It slacks rapidly on exposure to air and sunlight, especially when much handled or subjected to long hauls by rail. As a rule the grain of the wood and the compressed trunks of trees with branches are plainly visible in the coal, but pockets and layers of shiny, black, textureless, brittle coal are scattered through many beds. These pockets become more apparent on exposure to weathering agencies, as they slack more rapidly than the woody parts.

There is apparently a slight change in the character of the lignite toward the west. Near Wibaux less woody material appears in it than at Medora and Sentinel Butte. At Glendive, still farther west, the lignite is almost entirely of the black, brittle variety. This change may be due to the fact that the coals at Glendive are much lower in the rock section than those farther east, and hence are older and have suffered a greater degree of metamorphism than the higher coals.

The impurities in the lignite consist mainly of sand and clay partings, which are difficult to separate in mining. Intimate mixtures of fine sand or clay and lignite, of irregular shape and extent, are rather common in the beds, and are not easily detected without close examination, as they have the same color as the lignite. Crystals of selenite or gypsum are also found.

The fact that the woody parts of the lignite are freer from impurities than the textureless parts is recognized by ranchmen and farmers, who usually throw aside the less desirable lignite in mining.

Heretofore the lignite has been little used except as a local fuel supply, but the fact that lignites similar in every respect are mined on a commercial scale at Lehigh, N. Dak., 40 miles to the east, and near Glendive, Mont., 25 miles to the west, seems to justify the statement that the field is one of growing importance.

Briquetting tests of North Dakota lignite have been made by the United States Geological Survey fuel-testing plant and by individuals. No binder is used, but the product is firm and gives excellent results, except when subjected to forced draft, which has the effect of disintegrating the briquets and carrying the unburned particles out through the smokestack.

Another consideration that adds materially to the value of the brown lignite is its surprising success in the producer-gas plant. The following statement has been made concerning the value of North Dakota lignite in the gas producer and gas engine:^a

The result of the steam test was so unsatisfactory that there is nothing by which a direct comparison can be made of the efficiency of the fuel used in the producer-gas plant as compared with the efficiency developed in the steam plant. Nevertheless a comparison of the results obtained on other coals under the steam boiler is instructive. The table shows that to produce one electrical horsepower hour in the producer-gas plant required 2.29 pounds of dry North Dakota lignite, whereas to produce the same result in the steam plant required 3.39 pounds of the best West Virginia coal. This means that North Dakota lignite, with the moisture eliminated, will do more work when used in a producer-gas plant than the best coal of the country will do in a steam plant.

Many detached terraces or flats along Little Missouri River are too small to justify the construction of expensive canal systems for the purpose of irrigation. In other parts of this general region such terraces, from 10 to 30 feet above water level, are being watered by pumping from adjacent streams, lignite being used as fuel. Lignite in abundance is at hand or within easy reach of most of the probable locations of such plants on the Little Missouri, and it seems likely that with the settlement of the country more use will be made of it for this purpose.

The samples for the following analyses were all taken from open pits where the coal was more or less weathered. It is believed that

^a Prof. Paper U. S. Geol. Survey No. 48, pt. 1, 1906, p. 111.

the analyses would be slightly different, especially with respect to their original moisture content, had the samples been taken from fresh faces of coal, out of reach of atmospheric agencies.

Proximate analyses of samples of lignite from the Sentinel Butte field, North Dakota-Montana.

[F. M. Stanton, chemist in charge.]

Laboratory No.....	5779	5781	5782	5784
Sample as received:				
Moisture.....	34.50	35.72	35.40	43.51
Volatile matter.....	29.76	31.88	38.25	25.23
Fixed carbon.....	28.53	23.54	20.71	24.87
Ash.....	7.21	8.86	5.64	6.39
Sulphur.....	.99	1.53	.84	1.04
Calories.....	3,730	3,538	3,781	3,230
British thermal units.....	6,714	6,368	6,806	5,814
Loss of moisture on air drying.....	21.00	23.30	17.00	32.60
Air-dried sample:				
Moisture.....	17.09	16.19	22.17	16.19
Volatile matter.....	37.67	41.57	46.08	37.43
Fixed carbon.....	36.11	30.69	24.95	36.90
Ash.....	9.13	11.55	6.80	9.48
Sulphur.....	1.25	1.99	1.01	1.54
Calories.....	4,721	4,613	4,555	4,792
British thermal units.....	8,499	8,302	8,200	8,626

5779. Sec. 16, T. 141 N., R. 105 W., North Dakota.
5781. Sec. 8, T. 141 N., R. 105 W., North Dakota.

5782. Sec. 25, T. 139 N., R. 105 W., North Dakota.
5784. Sec. 5, T. 139 N., R. 104 W., North Dakota.

ESTIMATED TONNAGE OF LIGNITE.

It has been estimated that the total amount of lignite in the field within 1,000 feet of the surface and 3 feet or more in thickness is approximately 33,126,269,000 tons, equivalent to one bed 36.94 feet thick covering an area of 792 square miles.

MINING OPERATIONS.

All mining in the field is done to supply local demands. One-eighth of a mile northeast of Medora a drift has been opened to the southeast for 70 feet on a bed of lignite at the base of the bluff. The same bed was formerly worked on the west side of Little Missouri River about one-fourth mile west of the railway station at Medora, where mining operations were carried on by the Northern Pacific Railway Company as early as 1884. These workings have been abandoned and the entries allowed to cave in, so that the lignite can not now be seen. Other openings from which lignite has been taken during the fall and winter months are found at many points in the field. Throughout most of the area lignite is the only fuel used, and the ranchmen and settlers mine and haul the few tons they need from the nearest available outcrop, which is commonly not many miles distant.

Timber suitable for mining operations is scarce except along the valley of Little Missouri River.

THE MILES CITY COAL FIELD, MONTANA.

By ARTHUR J. COLLIER and CARL D. SMITH.

INTRODUCTION.

The Miles City coal field, situated in the northern part of Custer County, Mont., about 90 miles west of the North Dakota line, is a small part of a large area of Tertiary coal-bearing rocks which extends from eastern Montana southward into Wyoming, northward into Canada, and eastward into North and South Dakota. The area as here described comprises about 1,000 square miles. Rocks and coals of the same age in Carbon, Dawson, Rosebud, and Custer counties, Mont., have been examined and described^a in previous reports of the Geological Survey, and detailed studies during 1907 of coal-bearing rocks of the same age in the Sentinel Butte field of North Dakota and Montana, in the Bull Mountain and Red Lodge fields of Montana, and in the Sheridan and Glenrock fields of Wyoming, are reported in this volume. The coals are generally of low grade and are classed as subbituminous and lignite.

The present report is a preliminary statement intended to give advance information regarding the coal resources of the field, leaving the more purely scientific questions for consideration at a later date, when the investigations in this and other parts of the region shall have been completed. It is based on a season's field work by the writers, who were assisted by Carroll H. Wegemann and Ralph W. Howell. Through July and August the party was in charge of Mr. Collier, who was called away to other work on September 1; at that time Mr. Smith suspended his work in the Sentinel Butte field and took charge of the party at Miles City, continuing in the field until November 1.

The purpose of the investigation was primarily to ascertain the limits of the area underlain by workable coal and to classify the coal lands. With these objects in view, copies of the original township plats were used as a base for geologic mapping. Although

^a Leonard, A. G., Coal in Dawson, Custer, and Rosebud counties, Montana: Bull. U. S. Geol. Survey No. 316, 1907, pp. 194-211. Darton, N. H., Coals in Carbon County, Montana: Idem, pp. 174-193.

many of the surveys in this region are old, a large percentage of the original monuments are still preserved, and no townships purporting to have been surveyed were found in which classification of the land was utterly impossible for lack of corners.

Owing to the facts that the strata are practically horizontal and that no coal is known below drainage levels, the areal distribution of the coal depends to a remarkable extent on the topography, and data were collected for a topographic map with a contour interval of 50 feet. The flat map (Pl. III) herewith presented is compiled from the various field sheets, with such reduction of scale as has been found necessary for the present publication.

GEOGRAPHY.

LOCATION OF FIELD.

The geographic location and outlines of the area examined are shown on the index map (Pl. III). Its relations to the eastern Montana coal fields, together with its more general geographic and commercial relations, are indicated on the coal map of the United States (Pl. I).

COMMERCIAL RELATIONS.

Miles City, the principal town of the field and the county seat of Custer County, is situated in the western part of the area examined, at the mouth of Tongue River, on the main line of the Northern Pacific Railway, which here follows the south side of Yellowstone River. The western extension of the Chicago, Milwaukee and St. Paul Railway also crosses the Yellowstone from the north a short distance above Miles City, and parallels the Northern Pacific through the town, crossing again to the north side a short distance below the area mapped.

Two stage roads lead from Miles City to the region south and east. The Ekalaka road, which extends eastward to Knowlton and thence southward to Ekalaka, is the only practicable way by which wagons can be taken from Miles City directly across to Powder River, badlands to the north and south rendering travel almost impossible. A road following up Tongue River gives access to the region south of Miles City. About 10 miles above the mouth of Tongue River Pumpkin Creek enters from the east side, and a road along this creek furnishes an easy line of travel across the divide to Powder River and to Powderville, 20 miles south of the area under discussion. There are also passable wagon roads extending approximately north and south along Powder River and Mizpah and Cottonwood creeks, east of Tongue River. West of Tongue River there are many routes by which wagons can be taken over the greater part of the district.

At present no coal is shipped away from this part of Montana. Miles City, with a population of about 5,000, furnishes the best market, but the coal is used for domestic purposes by nearly all the ranchmen and farmers throughout the surrounding country. The largest individual consumers at the present time are the electric light and water companies of Miles City.

A broader field of usefulness for these fuels will probably be found in the production of power for irrigating many small detached tracts of land for which elaborate systems of canals are impracticable. Such tracts are especially numerous along Tongue and Powder rivers, and several pumping plants, some of which use steam and others gasoline engines, are already in operation.

The valley of the Yellowstone is in most places broad, but the meandering of the stream from bluff to bluff has left the flats disconnected. Two such flats, known as Sadie Bottom and Keogh Flat, lie a short distance above Miles City, and a project to irrigate them by pumping water from the Yellowstone, using the lignite near by as fuel, is under consideration by the Reclamation Service. About 9,000 acres along Tongue and Yellowstone rivers are under irrigation by a ditch which takes water out of Tongue River 10 miles above its mouth.

DRAINAGE.

Yellowstone River, rising in the Rocky Mountains several hundred miles to the southwest, flows diagonally across the northwest corner of the field and carries a large volume of water during all seasons of the year. Tongue and Powder rivers, rising in the Bighorn Mountains of Wyoming, flow northward across the area and join the Yellowstone. Both of these streams are perennial, but during the latter part of the summer water in them is extremely low. Back from the valleys of these master streams the region is drained by an intricate network of intermittent watercourses, usually in narrow canyons or gulches. Moon, Pumpkin, Mizpah, Cottonwood, and Locate creeks, the principal tributaries of the main rivers, usually contain water in pools, but do not flow continuously except in wet seasons.

TOPOGRAPHY.

The total relief between the highest and lowest points in the field does not exceed 900 feet, but much of the topography is exceedingly complicated in detail. Four rather distinct topographic types—lowlands, plateaus or uplands, badlands, and river terraces—can be recognized and are indicated on the profile accompanying Pl. III. The lowlands are situated in the valleys of the larger streams and include most of the irrigable land.

The upland areas comprise an undulating surface at elevations from 500 to 900 feet above the main drainage levels. Although these plateaus are somewhat uneven and in places are broken by buttes and canyons, they include large tracts level enough for cultivation, but not susceptible to irrigation for lack of available water. The largest upland area southeast of Miles City, known as the Pine Hills country, where dry-land farming has been successfully practiced for several years, is rather thickly settled.

The most distinctive topographic features of this region are its badlands, which almost everywhere surround the upland areas and form a ragged fringe separating them from the lowlands of the valleys. In these areas the topography is broken into intricate detail. Drainage is maturely developed and is affected by a multitude of intermittent watercourses in narrow canyons, which conform to no general system. The interstream areas are eroded into sharp peaks and ridges or narrow mesas at various elevations. In general, the individual hills and spurs or topographic units are comparatively small. The relief from canyon to hilltop in few places exceeds 200 feet, but the multitude of such features makes the badlands exceedingly difficult to traverse and renders them unfit for anything except grazing. The line of demarkation between the lowland and the badland areas is usually distinct and definite, the badland bluffs and buttes rising abruptly at the edges of the valleys.

In many places along Yellowstone and Powder rivers there are broad benches or terraces from 100 to 250 feet above river level. These terraces represent former valleys of the streams where gravel, which now serves as a protecting cap, was deposited. As they occur in the midst of the badlands they are rendered conspicuous by the abrupt change of topography. The terraces are too high above the level of the streams to be irrigated, but they are valuable for their production of wild hay, and may become more valuable for dry-farming purposes.

A noticeable feature of the region—one which adds picturesqueness as well as roughness to the badlands—is the red clinker or partly fused and baked sand and clay due to the burning of coal beds. Owing to the superior resistance of this material it has withstood the processes of erosion longer than surrounding softer rocks, and is thus left capping buttes and ridges and fringing the outcrops of unburned coals.

GEOLOGY.

STRATIGRAPHY.

Except for some unimportant alluvial deposits in the valleys all the rocks exposed in this district are of Tertiary age and belong to a formation called the Fort Union, which has been recognized in many

parts of Montana, Wyoming, North Dakota, and South Dakota. It is named after Fort Union, an old military post at the mouth of Yellowstone River. The total thickness of the formation can not be determined in this field, as neither top nor base is represented. The rocks consist of comparatively fine material, mainly clay shale and sandstone, including lignite and thin beds of impure limestone. They are all fresh-water deposits and contain an extensive fossil flora of about 400 species of plants which resemble those of modern times, and a fauna including fishes, fresh-water mollusks, and reptiles. Evidence now in hand indicates that the waters in which these sediments were deposited extended from east-central Wyoming to northern Montana, and from Livingston, Mont., eastward to the center of North Dakota. Within these limits areas not occupied by Fort Union rocks are those in which, owing to deformations of the earth's crust, they have been removed by erosion.

The total thickness of Fort Union rocks exposed in the Miles City field is about 900 feet, which may be increased by data obtained from drill holes at Miles City to a total of 1,400 feet. From a comparison of the section at Miles City with that exposed about 70 miles to the northeast near Glendive it is inferred that the base of the Fort Union formation is not very deeply buried, and it is probable that some of the drill holes at Miles City have penetrated to underlying Cretaceous rocks.

The Fort Union rocks exposed are readily separated into two members by a marked difference in lithologic character. The lower member, about 500 feet thick, consists mainly of alternating beds of clay shale and sandstone, having a general dark-gray or somber hue. In detail the individual layers of this part of the formation, especially the sandstones, show numerous irregularities of deposition. Thin layers of ferruginous limestone occur at short intervals throughout the section, and concretion-like masses of the same material, more or less lenticular in form, are included in the shales and sandstones. The thicker sandstone beds are usually characterized by more or less irregular cross-bedding. Coal is found at numerous horizons, but the beds are extremely variable in thickness and horizontal extent. The many alternations of soft rocks with thin hard layers give rise during erosion to marked badland topography.

Altogether sections of the rocks vary greatly in their detail from place to place, certain general features, such as thicker coal beds at or near certain horizons and prevalent sandstones or abundant concretions at others, can be recognized in a general way throughout the field. The following section, measured in detail near Miles City, is inserted to illustrate the rapid alternation of various materials comprising this part of the Fort Union formation:

Section of the lower member of the Fort Union formation near Miles City, Mont.

	Ft.	in.
Limestone at base of upper member.....	3	
Shale, white.....	7	
Coal and shale, dark.....		6
Shale, gray.....	20	
Limestone, weathering brown.....	1	
Shale, light gray.....	10	
Shale, dark gray.....	8	
Limestone, weathering reddish brown.....		6
Shale, dark yellow.....	6	
Coal.....		6
Shale, gray.....	21	
Limestone, weathering light red.....	1	
Shale, gray.....	25	
Sandstone, white, with limestone concretions.....	8	
Shale.....	2	
Sandstone.....	8	
Shale, white.....	2	
Shale, gray.....	5	6
Sandstone, gray.....	20	
Limestone, weathering red.....		3
Sandstone, gray.....	4	
Limestone, weathering red.....		6
Sandstone, gray.....	4	
Coal and shale.....	1	10
Sandstone, gray.....	3	6
Limestone, weathering light red.....	1	6
Sandstone, gray.....	4	
Limestone, weathering light red.....		6
Shale, dark.....	3	
Limestone, weathering red.....		3
Sandstone, gray.....	2	
Coal.....		8
Shale, yellow.....	5	
Limestone, weathering light red.....		8
Shale, gray.....	13	
Limestone, weathering red.....		6
Sandstone, fine gray.....	3	
Limestone, weathering red.....		2
Sandstone, gray.....	2	
Limestone, weathering red.....		2
Sandstone.....	5	
Coal (Weaver bed) (D, Pl. III).....	2	5
Shale.....		4
Coal.....	1	3
Shale.....		10
Coal.....		6
Shale.....		6
Coal.....		3
Shale, sandy, dark yellow.....	6	
Limestone, brittle.....		6
Shale, dark gray.....	5	

	Ft.	in.
Shale, fissile, dark brown	4	6
Coal		
Shale, gray, with numerous limestone concretions.....	17	
Limestone, weathering red.....		6
Shale, dark, with thin layers of red limestone.....	10	
Sandstone, brown, containing fragments of carbonaceous material	7	
Coal	1	6
Shale, light gray.....	9	
Limestone, red		2
Shale		3
Coal		3
Shale, blue	8	
Coal, with three small streaks of bone.....	3	4
Sandstone.....	6	
Shale	4	
Sandstone.....	2	6
Shale	3	
Coal		7
Shale		6
Coal, dirty, with several white partings, one-half inch to 1 inch thick (Laney bed) (C, Pl. III)		5
Shale	1	
Sandstone.....	2	
Shale	4	
Limestone, weathering red		6
Sandstone, gray, with some thin layers of shale.....	25	
Limestone, weathering red.....		6
Shale, sandy, yellowish gray.....	8	
Coal		8
Shale	3	
Sandstone, friable, gray	20	
Shale, sandy, many concretions	5	
Limestone, weathering red.....	3	
Sandstone, coarse, gray.....	17	
Limestone, weathering light red.....		6
Sandstone.....	3	
Shale, brown with blue bands	10	
Sandstone.....	6	
Coal and shale.....	2	
Shale, sandy, gray, usually cross-bedded.....	50	
Coal		6
Shale, sandy.....	5	
Coal (Kircher bed) (A, Pl. III)	5	

465 3

This member is conformably overlain by more homogeneous rocks, mainly sandy shale, which, as exposed by erosion, are generally of a light-yellow color. This member of the Fort Union formation is here designated the upper member. The somber color which prevails in the lower part of the formation is represented in the upper part only by an occasional bed of gray or light-blue shale.

Coal beds in this member are not so numerous near Miles City as in the lower member, but are more constant in thickness and quality. The workable coal is confined to two beds, 160 and 300 feet above the base of the member.

In some places these rocks give rise to badland topography, but in general the features are larger than those produced in the somber-colored beds below; the hills and buttes are higher and the level stretches more extensive. Calcareous layers such as occur in the lower beds are not expressed in the topography, but many of the buttes are capped with the clinkers of burned coal. The characteristic features of these two members of the Fort Union formation indicate conclusively that the conditions which prevailed during the deposition of the lower member were much more changeable than those during the deposition of the upper. When the lower beds were deposited shallow-water conditions evidently prevailed, with shifting currents and changes of elevation too frequent to permit the formation of extensive beds of coal. The carbonaceous materials in many of the coal beds are thoroughly macerated, and no doubt in some places were partially decomposed by exposure to air before the overlying strata were laid down. During the deposition of the upper beds general conditions were more stable, and consequently the different layers of this part of the formation are more uniform both in thickness and distribution. Though there is some false bedding, it is neither so common nor so well marked as in the lower beds. The coals retain more of their original woody texture and are distinctly lignitic in appearance.

STRUCTURE.

Throughout the area under discussion the strata, except where they are locally displaced by surface influences, lie perfectly flat. No deep-seated faults have broken them, though in some localities displacements of a few feet, attributable to purely local conditions, have been observed. As a result of this simple structure no rocks lying below the level of Yellowstone River are exposed. Individual coal beds may be traced and correlated with certainty throughout the field, and their outcrops coincide with contour lines. The map (Pl. III) showing in detail the outcrops of the more important coal beds has the appearance, therefore, of a contour map with irregular contour interval.

Some facts, however, indicate that either all or a large part of the field lies in a shallow syncline or basin. A number of wells drilled at Miles City yield a fair flow of artesian water which, in order to reach the surface, must have descended along bedding planes from some higher levels. It is thought that the source of this water is to the west of the field, where there is some evidence that underlying Cretaceous rocks outcrop at Howard, on the Yellowstone. The rise of

the rocks in that direction is scarcely greater than the gradient of the river. About 70 miles northeast of Miles City, near Glendive, there is a pronounced anticline, which brings the Pierre shale to the surface. This flexure has a northwest-southeast axis and is believed to mark the northeast limit of the basin in which Miles City is situated. A few miles south of this district the lower member of the Fort Union formation rises to the summit of the divide between Tongue and Powder rivers, and it is thought that here also there may be a broad anticline separating the Miles City field from the Sheridan field of Wyoming.

THE COAL.

GENERAL CONDITIONS.

Coal beds are distributed at short intervals through the entire section of rocks exposed, but many of them are too thin to work, or, if thick enough to work, are too impure for commercial use. The drill holes sunk about Miles City in search of artesian water have revealed no coal beds of consequence to a depth of 500 feet below the river level, indicating that the Kircher coal, which lies about 50 feet above river level, is the lowest workable bed and practically the base of the coal-bearing rocks.

A distinct change in the character of the coals, as in that of the other strata, can be noted in passing from the lower to the upper beds. The former vary greatly in thickness and purity from place to place. In many localities they contain numerous thin partings and seem to have been deposited under changeable conditions. On close examination a majority of the lower coals are found to be black in color and to exhibit comparatively little of the woody texture characteristic of the higher coals. The absence of woody texture is attributed to more complete maceration of the carbonaceous material during the time of its deposition.

The character of the lignite in the upper beds indicates that the conditions during its deposition were comparatively stable; the beds are more uniform in thickness and contain fewer sand and clay partings than the lower beds. The coal-forming material suffered little change while accumulating, for its woody texture is clearly visible. In luster and color the coal is more lignitic than that of the lower beds, and it is more liable to spontaneous combustion, as is shown by the prevalence of clinkers along the outcrop of the beds.

The number of coal or lignite beds visible in the badlands has naturally led to the conclusion that great quantities of coal are available in the immediate vicinity of Miles City, but although it is true that the quantity is great the percentage that can be mined economically is relatively small, and before any large area is purchased for mining purposes it should be thoroughly tested by drilling. In the upland

regions comparatively little coal is exposed in natural outcrop, but the beds present are more uniformly valuable and the areas which can be regarded as coal land are larger than in the badlands.

EVIDENCE OF BURNED COAL.

In many places, especially in the areas underlain by the upper member, the thicker beds of lignite have burned along their outcrop, and the adjacent rocks, together with the clay and sand partings of the lignite beds, have been metamorphosed and hardened. The resulting rock has a general red color, though it ranges from only slightly altered shale and sandstone to black vesicular slag resembling lava, for which it has often been mistaken. The prevailing red color is doubtless due to the presence of iron, which has been partly reduced, so that these rocks interfere slightly with the working of the magnetic needle. Where the cover is great the extent of burning back from the outcrop is limited, and it can probably be safely assumed that the lignite is intact under a cover of 100 feet. There are, however, large areas fringed by outcrops of clinker in which the cover is thin and where the burning seems to have extended back for an indefinite distance. Many extensive mesas are capped with clinker under a slight cover of soil and in such places it is difficult to distinguish the unburned from the burned areas. The unburned lignite, where it outcrops on grassy slopes, is usually covered with soil and is hidden. Its presence is here and there revealed by the burrowings of prairie dogs or by the cutting of streams, but such evidences are rare. That much of the burning occurred as early as Pleistocene time is indicated by clinker pebbles in the bench gravels of some of the canyons, as well as by the extensive erosion and dissection of the clinker beds. The topography produced offers an important line of evidence as to the extent of the burning. Many of the unburned areas occur in rounded hills, which are fringed with clinker-covered benches and low ridges, separated from the unburned areas by shallow valleys, a few rods wide, due to erosion. Such valleys have clinkers on one side and grassy slopes on the other. There are many variations of this feature, which depend on the amount of erosion since the burning and the relation of the general drainage. Many of the streams flowing from the unburned areas across the clinker rim have in their upper parts wide valleys with grassy slopes, which contract to box canyons in crossing the burned portions. An example of this feature can be seen at the edge of the Pine Hills, 10 miles out from Miles City on the Ekalaka road. This road crosses a clinker rim through a narrow canyon which widens into a small valley above the rim, and the wash in the side of the road here reveals the blossom of unburned coal at the level of the clinker.

There are probably many such small areas of unburned coal in the Pine Hills country, and some of them may be of economic value but could not be differentiated in the field for lack of evidence as to their extent.

EXPLANATION OF THE MAP.

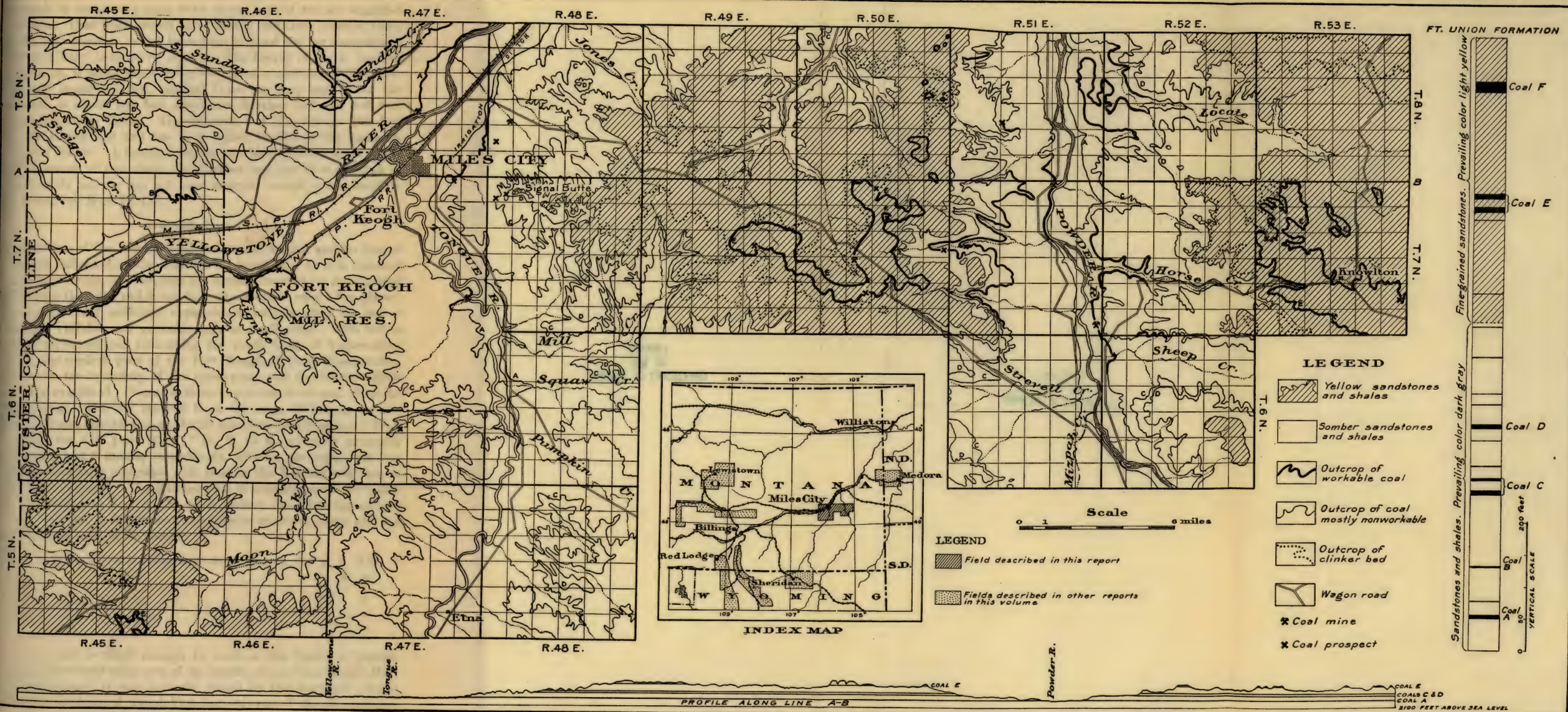
On the accompanying map (Pl. III) the areas occupied by the lower and upper members are differentiated, the former being left blank and the latter ruled with parallel lines. The contact of these two members coincides with a contour line 2,850 feet above the sea, or 550 feet above the level of the Yellowstone. Owing to the intricate detail of topography this line is somewhat generalized. The outcrops of five of the more important coal beds designated by the letters A, C, D, E, and F are traced on the map and coincide with the contour lines at various levels indicated in the columnar section at the right. The stratigraphic relations are also shown in the profile at the bottom of the map. The character of the coal bed along the outcrop is indicated by the weight of the line. Wherever the coal bed has been found to be workable its outcrop is traced in a heavy line, and the detail is drawn with as great accuracy as possible, but where the bed is not known to be workable its outcrop is shown by a light line, which has been somewhat generalized. In the upper member the lignite in many places has been burned for an unknown distance back of the outcrop, and the limits of unburned and therefore workable lignite have been placed at a safe distance back of the outcrop indicated by clinkers. The edges or outcrops of the clinker due to the burning of the bed lettered E are shown by lines of dots, and a critical examination of the map will give an idea of the quantity of burned lignite in this bed as compared with that remaining in the district.

COALS OF THE LOWER MEMBER.

GENERAL OUTLINE.

The coals of the lower member are black and usually show little of the woody texture common to the lignite higher in the section. They are fairly brittle and have an even fracture. Joints and slips transverse to the bedding are not prominent, but such features have been observed in some of the mines and openings. When freshly mined the coal has a bright luster, but this is soon lost in the process of slacking, which begins as soon as the coal is exposed to the air. It is estimated that there is an average of at least one bed of coal or carbonaceous shale for every 50 feet of thickness in this part of the Fort Union formation, but less than 1 per cent of the coal exposed in outcrop is of workable thickness and purity, if no coal beds under





MAP OF THE MILES CITY COAL FIELD, MONTANA.

By A. J. Collier, C. D. Smith, and C. H. Wegemann.

3 feet thick or containing more than 20 per cent of ash are regarded as workable. Coal beds known to be locally workable occur at three rather definite horizons, which have been mapped and for convenience of reference have been given names. The lowest of these, marked A on the map, is called the Kircher bed, from a mine near Miles City. The second important bed, marked C on the map and called the Laney bed, is about 200 feet above the Kircher bed and 250 feet above Yellowstone River. The Weaver bed (D) occurs 100 feet above the Laney bed and has been mined locally in the badlands near Signal Butte. A fourth horizon, at which there is some workable coal, occurs 60 feet above the Kircher bed, but it is so small in extent that its outcrop has not been mapped except in one locality, which is marked B on Pl. III.

KIRCHER COAL.

The position of the Kircher coal bed in the section and its line of outcrop are indicated on the map by the letter A. As it is situated near drainage levels, its croppings are usually covered by river gravel or wash from the hills, and it has been examined in only a few places. There are, however, sufficient exposures to indicate that the bed is exceedingly variable and workable only in small areas. This bed is well exposed in railroad cuts along the south bank of Yellowstone River, in the western part of the Fort Keogh Military Reservation, and between the boundary of the reservation and the western limit of the area examined. Some of these exposures show coal of workable thickness. The bed marked B on the map, 60 feet above the Kircher horizon, also attains workable thickness locally in the NW. $\frac{1}{4}$ sec. 25 and the SW. $\frac{1}{4}$ sec. 27, T. 7 N., R. 45 E., where it measures 3 feet and 3 feet 9 inches, respectively, without partings. Its line of outcrop so nearly coincides with that of the Kircher bed that it has not been mapped. The Kircher coal is workable for a few miles along its outcrop in T. 7 N., R. 45 E., where the following section was observed, but it is thin and unworkable on Moon Creek and for a mile east and west of its mouth:

Section of Kircher coal bed in railway cut in the SE. $\frac{1}{4}$ sec. 33, T. 7 N., R. 45 E.

	Ft. in.
Coal.....	1 6
Clay.....	2
Coal.....	1 8
	3 4

The same bed is thick enough to work in the banks of Lignite Creek and for several miles east of its mouth, on the Fort Keogh Military Reservation. It was formerly mined by the Northern Pacific Company at the head of Keogh Flat, but only one of the old openings

is in such condition that a section can be measured. The character of the bed here is shown by the following sections:

Section of Kircher coal bed on Lignite Creek at county-road crossing, three-fourths mile south of Northern Pacific Railway, on Fort Keogh Military Reservation.

	Ft.	in.
Coal.....	1	9
Clay.....		1
Coal.....	1	6½
Clay.....		4
Coal.....		9¼
Clay.....		2
Coal.....		9
Total coal.....	4	9¾

Section of Kircher coal bed at head of Keogh Flat.

	Ft.	in.
Coal.....	1	2
Clay.....		6
Coal.....	3	4
Total coal.....	4	6

Eastward from the head of Keogh Flat the outcrop of this bed follows the base of the hills to Tongue River, where it turns southward and follows up the west bank of the river for 6 or 7 miles. The coal shows a workable thickness at only one point in this stretch, viz, at what is called the Weaver mine, on the west bank of Tongue River, 5 miles south of Miles City, where it is 4 feet 4 inches thick, without partings, and has been opened by a number of short, temporary drifts, the product being hauled to Miles City in wagons. East of Tongue River the outcrop of this bed follows the base of the hills and practically coincides with the margin of the lowlands or river flat, but for several miles there is no evidence that the bed contains workable coal. It is of better quality, however, a short distance east of Miles City, and has been exploited by a number of small mines, only one of which is active at the present time. At the Kircher mine, in the SE. ¼ sec. 19, T. 8 N., R. 48 E., the bed is 60 feet below the surface and is reached by an incline. It averages 5 feet thick and has a 2-inch parting described as "grit" near the center. The floor is hard clay, which heaves when wet. The roof is also hard clay, and 8 inches to a foot of coal is usually left to support it. A section measured here is as follows:

Section of coal bed at the Kircher mine, in sec. 19, T. 8 N., R. 48 E.

	Ft.	in.
Coal.....		1
Shale.....		6
Coal.....		4
Shale.....		2
Coal.....	2	6
Bone.....		1
Coal.....	2	6
Total coal.....	6	4

The mine is worked both winter and summer, and the product is hauled in wagons to Miles City, a distance of approximately 6 miles.

Northeast of the Kircher mine there are no exposures of this bed within the area examined, but it is reported that prospect holes have demonstrated that much of the coal is of no value. The same bed has been mined for many years north of Yellowstone River opposite Miles City, in sec. 22, T. 8 N., R. 47 E., at what was formerly known as the Comstock mine but is now called the Hedges mine. During the summer of 1907 a new opening was made on the coal bed from the river bank, and it is proposed to transport the coal from this opening across the river by means of a cable tramway. A section of the coal bed measured here is as follows:

Section of the Kircher coal bed at the Hedges mine, in sec. 22, T. 8 N., R. 47 E.

	Ft.	in.
Coal.....	7	$\frac{1}{4}$
Clay.....		$\frac{3}{4}$
Coal.....	1	$9\frac{1}{2}$
Clay.....	1	9
Coal.....	1	6
Total coal.....		3 10 $\frac{3}{4}$

West of the Hedges mine the outcrop of the coal is traceable along the river bank for several miles, but within a short distance the bed is divided and contains partings, so that it does not show workable thickness. It has also been traced along the river bluffs northeastward from the Hedges mine, and in this direction also the parting increases in thickness until at the northern boundary of the area examined it is worthless for mining. What is regarded as the same bed outcrops along Sunday Creek, several miles north of the Hedges mine, where it has been worked by stripping at a number of places. The outcrop is about on a level with the creek, and there are few good exposures. A section measured near the forks of Sunday Creek showed about 5 feet of workable coal.

Section of Kircher coal bed in sec. 13, T. 8 N., R. 46 E.

	Ft.	in.
Coal.....	1	9
Clay.....		$\frac{3}{4}$
Coal.....	2	5
Clay and bone.....		4
Coal, base concealed.....	1	1
Total coal.....		5 3

A section measured near the point where Sunday Creek crosses the northern boundary of the area examined showed a little over 4 feet of workable coal.

Section of Kircher coal bed on Sunday Creek, near north line of T. 8 N., R. 46 E.

	Ft.	in.
Coal, bony.....	1	
Clay, blue.....	1½	
Coal, bony.....	2½	
Clay.....	½	
Coal.....	2	
Sand.....	½	
Coal.....	2	2
Shale, gray.....	1	
Coal.....	1	9
Total coal.....	4	4½

Between Tongue and Powder rivers this bed is not exposed, and though it is no doubt workable in some places the areas in which it is of economic value can not be located without drilling. In the greater part of this district its depth is less than 600 feet, and it is nowhere more than 900 feet below the surface. It outcrops in workable thickness in the left bank of Powder River in sec. 2, T. 7 N., R. 51 E., where it is mined to supply fuel for a small irrigation plant. The section of the bed is as follows:

Section of Kircher coal bed in sec. 2, T. 7 N., R. 51 E.

	Ft.	in.
Coal.....	1	11
Bone parting.....		¾
Coal.....	1	10
Total coal.....	3	9

The bed is exposed at intervals along the river bank for about 2 miles to the south, where it is probably workable but somewhat thinner than at the mine. North of the mine it is concealed for a considerable distance, but an exposure in sec. 23 in the same township shows less than 1 foot of coal. A bed which is of workable thickness locally has produced some coal from a short drift on Brown's ranch, in sec. 36, T. 7 N., R. 51 E., and has been traced for several miles along the bluffs. This bed is 10 to 20 feet above Powder River, and should possibly be correlated with the B coal bed, which lies about 60 feet above the Kircher bed. It contains over 3 feet of coal at Brown's ranch, as shown by the following section:

Section of coal bed on Brown's ranch, sec. 36, T. 7 N., R. 51 E.

	Ft.	in.
Coal.....	2	10
Shale.....		1
Coal.....		8
Total coal.....	3	6

At the mouth of Horse Creek, 1½ miles north of Brown's ranch, the bed is divided and of no value. It is of sufficient thickness for

mining at the mouth of Sheep Creek, in sec. 1, T. 6 N., R. 51 E., but is not over 1 foot thick in the river bluff at the county bridge in sec. 30, T. 6 N., R. 52 E.

LANEY COAL.

A second zone in which there is a large quantity of coal that is workable in some places but generally too impure for mining lies from 160 to 200 feet above the Kircher bed and is marked C on the map and section (Pl. III). This zone is not a single bed, but usually is made up of two or more beds within a range of 50 feet vertically. As a rule the coals contain a great number of thin sandy-clay and bone partings. The largest bed is 10 feet thick in many places, but the utter impossibility of separating the thin partings from the coal unfits it for mining.

These beds have been opened at many places near Miles City, but operations have been discontinued on account of the impurities in the coal. They are also exposed on Cottonwood Creek, midway between Tongue and Powder rivers, where the thickest bed has been mined for local supply. The coal is generally of better quality, however, along Powder River, where it shows to the best advantage near Laney's ranch, from which it takes its name.

North of Yellowstone River, in the northwest corner of the field, these coals are extremely variable in thickness and always dirty, and in no place seen do they appear to be workable.

In the area west of Tongue River and south of the Yellowstone they are also extremely variable in thickness and purity, and appear as a conspicuous dark zone in the badlands of the Fort Keogh Military Reservation. In the western part of the reservation and between the reservation and the boundary of the area here mapped, the croppings of the beds are almost completely concealed by bench gravel, but on the divides east and west of Lignite Creek and thence eastward to the breaks of Tongue River their outcrops are almost continuously exposed in the bare bluffs of the badlands. The section given below shows the character of the beds:

Section of the Laney coal bed in the southeast corner of Fort Keogh Military Reservation.

	Ft. in.
Coal.....	2
Clay and coal.....	3 6
Coal.....	2 6
Sandstone.....	10
Coal.....	6
Sandstone.....	15
Coal.....	2
Clay.....	15
Coal, dirty.....	2 6
Clay.....	3
Coal, dirty.....	3 4
Total coal.....	11

The uppermost coal bed in the above section becomes locally thicker and may be workable in places in T. 6 N., R. 47 E. A section follows:

Section of Laney coal bed in the SE. $\frac{1}{4}$ sec. 22, T. 6 N., R. 47 E.

	Ft.	in.
Coal.....		8
Bone.....		1
Coal.....	1	2
Bone and dirt.....		8
Coal.....	2	
Clay.....	1	
Coal.....	1	
Bone.....		7
Coal.....	1	6
Total coal.....	6	4

Southward from this locality the coal outcrops at many places, but is everywhere divided by thin clay partings which render it unworkable.

One of the beds is locally workable in the divides between Mill, Squaw, and Pumpkin creeks, in T. 6 N., R. 48 E., where it contains 3 feet 4 inches of workable coal near the northwest corner of sec. 25 and 4 feet near the east quarter corner of sec. 12. These measurements are exceptional, however, as many other exposures of the bed in the same vicinity show numerous clay partings in the coal. Some of the beds are probably also workable in a few places in T. 5 N., R. 48 E., but the presence of characteristic thin clay partings renders most of the coal unfit for mining.

Many attempts to work these coals have been made in Tps. 7 and 8 N., R. 48 E., but all the openings have been abandoned on account of the impurities in the coal. The following section of the beds at this horizon was measured near Signal Butte, in sec. 6, T. 7 N., R. 48 E.:

Section of Laney coal beds near Signal Butte.

	Ft.	in.
Coal.....	1	6
Shale, light gray.....	9	
Limestone, weathering red.....		2
Shale.....		3
Coal.....		3
Shale, blue.....	8	
Coal with three small streaks of bone.....	3	4
Sandstone.....	6	
Shale.....	4	
Sandstone.....	2	6
Shale.....	3	
Coal.....		7
Shale.....		6
Coal, dirty, with white partings, 6 inches to 1 foot thick....	4	5
Total coal.....	10	1

Some coal has probably been produced from the large bed at the base of this section, but the numerous thin bony layers are so uniformly distributed as to render it of little value. No sample of the coal was taken for analysis, but it was estimated in the field that the ash surely exceeds 25 per cent. In view of the quantity of better coal in other beds near at hand, it is hardly possible that this bed can ever be mined at a profit. The 3-foot bed which lies about 15 feet higher in the section has also been developed, but was abandoned on account of the bad roof and the impurities of the coal. Three miles southeast of Signal Butte, near the center of this township, the two upper beds of the section come nearly together, and the combined bed thus formed is probably barely of workable thickness.

The exposures of coal at the Laney horizon along Cottonwood Creek in T. 8 N., Rs. 49 and 50 E., show similar conditions. The thickest bed has been worked for local supply from cut banks of Cottonwood Creek, where it is 10 feet thick but contains many thin partings that can not be separated from the coal.

The Laney coal is generally of better quality where exposed in the bluffs and badlands of the Powder River valley, and the areas regarded as workable are indicated on the map (Pl. III). It is burned along the outcrop at many places in this district, producing a heavy clinker bed.

The coal is of workable thickness for several miles along the outcrop in T. 7 N., R. 51 E., west of the Laney ranch, where it shows to the best advantage, and an exposure in sec. 21, T. 7 N., R. 51 E., indicates approximately 15 feet of good coal.

Section of Laney coal bed in sec. 21, T. 7 N., R. 51 E.

	Ft.	in.
Coal.....	3	6
Shale, carbonaceous.....	2	
Coal.....	8	3
Shale.....		9
Coal.....		6
Shale.....	1	
Coal.....	1	
Shale.....		2
Coal.....	2	
Shale.....		3
Coal.....	2	
Total coal.....	17	3

The quantity of coal decreases north and south of this locality, and within a few miles in either direction the bed is too poor to be of value. East of Powder River the Laney bed is exposed in workable thickness at several places below the gravel of an extensive terrace 250 feet above the river. In general the exposures are poor, and it is possible that there may be more coal here than the map indicates.

Five feet of coal in one bench shows in sec. 13, T. 8 N., R. 51 E., and scattered exposures of part of the bed indicate that it is valuable as far as mapped. A bench containing 3 to 4 feet of coal is exposed at intervals for several miles in the east side of T. 7 N., R. 51 E., but the exposures are poor and no complete section of the bed can be given.

WEAVER COAL.

At an elevation of about 100 feet above the Laney coal, or 350 feet above Yellowstone River at Miles City, a group of coal beds occur to which the name Weaver has been given. One of the beds of this group has been mined at the base of Signal Butte by Mr. Weaver, of Miles City. In distribution this bed conforms roughly to the Laney coal bed, but as it is higher in the section it underlies less territory.

In the northwest corner of the district, north of Yellowstone River, this coal bed is confined to the area south of South Sunday Creek, almost all of it occurring in T. 8 N., R. 45 E. The bed is usually divided into two benches and is filled with small partings, which spoil it for mining. In the area south of the Yellowstone and west of Tongue River it is also poor. Some sections follow:

Section, including Weaver coal bed, in south-central part of Fort Keogh Military Reservation.

	Ft.	in.
Coal and clay in equal parts.....	6	
Clay.....	30	
Coal.....		6
Clay, carbonaceous.....	3	6
Clay, sandy.....	7	
Coal, dirty.....	2	10
Total coal.....	9	4

Section of the Weaver coal bed in the southwest corner of T. 5 N., R. 47 E.

	Ft.	in.
Coal, dirty.....	2	6
Clay, sandy.....	4	6
Coal, dirty.....	2	
Total coal.....	4	6

In Tps. 5 and 6 N., R. 48 E., this bed has a meager distribution, but is rendered worthless by partings.

At the old Weaver mine near Signal Butte, sec. 6, T. 7 N., R. 48 E., the bed contains 4 feet of coal, but is divided into several benches, and the coal, as shown by analyses, is very impure. The section is as follows:

Section of coal bed at Weaver mine near Signal Butte, sec. 6, T. 7 N., R. 48 E.

	Ft.	in.
Clay, brown, carbonaceous.....	10	
Coal.....	2	2
Clay.....	1	
Coal.....	2	
Clay.....	3	
Coal.....	1	5
Clay, carbonaceous.....	4	
Coal.....	1	2
Clay.....		
Total coal.....	4	11

Only the two upper benches are mined.

North of Signal Butte the Tongue River badlands contain no exposures of this bed that indicate a workable thickness.

On Cottonwood Creek, in T. 8 N., Rs. 49 and 50 E., a bed at this horizon was traced for many miles, but nowhere shows a thickness exceeding 2 feet 8 inches. The coal, however, appears to be of good quality and will doubtless be mined to some extent for local supply. West of Powder River, near the head of Laney Creek, in T. 7 N., Rs. 50 and 51 E., a bed at or near this horizon overlies the Laney coal and is regarded as workable for several miles along its outcrop, where it contains approximately 3 feet of coal without partings. East of Powder River no exposures of this bed were seen in which the coal could be regarded as workable.

LIGNITES OF THE UPPER MEMBER.

GENERAL OUTLINE.

The lignites of the upper beds are dark brown in color, usually tough and woody in texture, but relatively uniform in distribution and purity. In these respects they differ considerably from the black, nearly textureless coals, already described. Valuable beds are found generally at two horizons, the lower of which is 160 feet above the base of the upper member; the upper about 300 feet above the base. These horizons are indicated on the map and section (Pl. III) by the letters E and F. In the field their outcrops are indicated by clinkers, and there are large areas in which the lignite has been wholly destroyed by fire.

In addition to these more important lignite horizons there are many thin beds, one of which, about 70 feet above the base of the member, is thick enough to work in at least two places. It measures slightly over 3 feet in sec. 28, T. 7 N., R. 49 E., and 4 feet at the Hill ranch, in sec. 27, T. 8 N., R. 50 E. These occurrences are regarded as local, however, as no lignite beds thicker than 1 foot have been discovered elsewhere at or near this horizon.

DOMINY LIGNITE GROUP.

The most important lignite in this field is that marked E on the map. It has been mined for local supply near Dominy's ranch, and is referred to as the Dominy lignite. It consists of a group of lignite beds having a vertical range of about 30 feet, some or all of which are workable wherever they have not been destroyed by burning.

Some idea of the former extent of this lignite group can be obtained from the distribution of the baked and fused material caused by its burning, from which it is inferred that lignite beds of this group formerly covered the whole area here described. The outcrop of these beds, except in a few places, is completely concealed by a fringe of clinker and baked material, which reaches in many localities a thickness of 100 feet. The areas in which this group of beds has not been destroyed are relatively small and many of them are difficult to locate.

Between Tongue and Powder rivers a comparatively large area in T. 7 N., Rs. 49 and 50 E., has been outlined, as shown on the map (Pl. III). The average thickness of workable lignite in this area is thought not to be less than 10 feet. In sec. 14, T. 7 N., R. 49 E., it measures 15 feet, and in sec. 28, T. 7 N., R. 50 E., 3 feet. Another section is given below:

Section of Dominy lignite group in sec. 3, T. 7 N., R. 50 E.

	Ft.	in.
Lignite.....	7	
Shale, sandy.....	13	
Lignite.....	3	6
Shale, sandy.....		8
Lignite.....	5	
Total lignite.....	15	6

The lowest bench of this section is represented by sample No. 5962 of the table of analyses (p. 57).

East of Powder River the known areas of the Dominy lignite, as shown by the map, are confined to T. 7 N., R. 53 E., near the town of Knowlton. Several sections of the beds were measured here.

Section of Dominy lignite bed in sec. 33, T. 7 N., R. 53 E.

	Ft.	in.
Lignite, dirty.....	6	
Lignite, good.....	1	2
Bone.....		4
Lignite.....	2	
Parting, sandy.....		1
Lignite.....	1	10
Total lignite.....	5	6

In sec. 7, T. 7 N., R. 53 E., 4 feet of lignite are exposed with both top and bottom concealed.

Section of Dominy lignite bed in sec. 18, T. 7 N., R. 53 E.

	Ft.	in.
Lignite.....	8	
Bone.....	8	
Lignite.....	3	3
Sand.....	3	
Lignite.....		
Bottom of section concealed.		
Total lignite.....	3	11

F LIGNITE.

The highest bed in the field, marked F on the map and section, has been so generally destroyed by fire as to be of little economic value. The only place where it was found in an unburned condition is in sec. 10 T. 7 N., R. 50 E. The bed evidently contains several feet of workable lignite, but its full thickness was not exposed. The total area of land containing the bed in workable condition does not exceed 5 or 6 acres.

QUANTITY OF AVAILABLE COAL.

In addition to the five coal beds whose outcrops have been mapped, there are many others that show in the badland bluffs of this field, but only a relatively small proportion of the coal exposed is of workable thickness and quality. The valuable coal lands are confined to small areas whose boundaries can not be determined closely without thorough prospecting. The writers have estimated the total quantity of workable coal in the areas classified as coal land at 780,080,000 tons, which is approximately equal to the tonnage of a bed 0.68 foot thick covering the whole field, but owing to the extreme variability of the coal beds the limit of error in this estimate is necessarily high. The figures given above are conservative and represent the coal which actually outcrops in workable thickness and quality. On taking into consideration the general distribution of the small areas of workable coal and its probable occurrence in other areas where there are no natural exposures, it is reasonable to assume that the total quantity of coal that may be developed by prospecting will be considerably more than the above estimate.

CHARACTER OF THE COAL.

PHYSICAL PROPERTIES.

The coals of the upper member in this field are brownish in color and those of the lower member are nearly black, but all give a brown streak when cut or scratched and make a brown powder when crushed. The weathered outcrop or blossom of the coals of either type is black. In general the upper lignites retain their original

woody texture and are tough; the lower coals have more the texture of higher-grade coals, though nearly all the beds contain some woody material. Joints have been observed in all the beds wherever they are well exposed. The joint planes are invariably wide apart, but are of considerable importance in mining, and for blasting the holes are usually bored parallel to them. The lumps of coal produced are generally of irregular shape. They begin to crackle and lose moisture immediately after mining and finally slack to fine flaky powder under atmospheric influences.

In burning the coals decrepitate rapidly, and if disturbed the fire is easily smothered. To obtain the greatest efficiency, the coal must be spread thinly over wide grates. It burns with a long, yellow flame, but does not produce much smoke.

CHEMICAL PROPERTIES.

All the samples of this coal which have been analyzed contain more than 29 per cent of moisture as they come from the mine, and after air drying they still retain from 10 to 18 per cent. The coals from the upper member usually contain from 8 to 10 per cent of ash and are apparently more impure than those from the lower member. The relative proportion of fixed carbon in the coal from the former is higher than in that from the latter. The fuel ratios (percentage of fixed carbon divided by percentage of volatile matter) of the lower coals average 1.20; those of the lignites higher in the section are considerably less. In efficiency the lower coals are greater than the higher lignites. From their obvious physical and chemical properties the former are classed as subbituminous and the latter as lignite.

Owing to the primitive nature of the developments in this field, only seven representative samples of unweathered coal were obtained for chemical analysis. These were collected from mines according to the method prescribed by the United States Geological Survey fuel-testing plant, as noted on pages 12-13.

Sample No. 5962 was collected near the outcrop where the lignite showed some indications of weathering. All the other samples represent unweathered coal. The samples collected last summer were not analyzed until several months after they were obtained, but all of them were sealed in air-tight cans. Before analyzing they were reduced to a uniform basis by exposing them to dry air, and the loss of moisture on air drying was determined. The analyses of the samples both as received and after air drying are given, but for purposes of comparison the analysis of the air-dried sample is preferable, as it represents more nearly the condition in which the coal would reach the consumer.

Proximate analyses and calorific determinations of coals and lignites from the Miles City field, Montana.

[F. M. Stanton, chemist in charge.]

Character of coal.....	Subbituminous.						Lignite.
Name of bed.....	Kircher (A).				Weaver (C).	Dominy (D).	
Location.....	Sec. 25, T. 7 N., R. 47 E.	Sec. 22, T. 8 N., R. 47 E.	Sec. 19, T. 8 N., R. 48 E.		Sec. 2, T. 7 N., R. 51 E.	Sec. 6, T. 7 N., R. 48 E.	Sec. 3, T. 7 N., R. 50 E.
Laboratory No.....	5780	783	5694	a 2425	5963	a 3701	5962
Sample as received:							
Moisture.....	29.52	29.21	29.60	30.25	31.75	29.13	35.51
Volatile matter.....	27.96	26.15	27.40	30.48	25.49	25.33	26.75
Fixed carbon.....	33.84	35.45	32.97	31.34	33.31	30.51	28.87
Ash.....	8.68	9.19	10.03	7.93	9.45	15.03	8.87
Sulphur.....	.70	.75	.68	.60	.70	.55	.40
Calories.....	4,286	4,260	4,156		4,078	3,701	3,535
British thermal units.....	7,715	7,668	7,481		7,341	6,662	6,363
Loss of moisture on air drying.....	14.00	15.40	18.10	21.90	20.00	16.50	22.90
Air-dried sample:							
Moisture.....	18.05	16.32	14.04	10.69	14.69	15.12	16.36
Volatile matter.....	32.51	30.91	33.46	39.03	31.86	30.34	34.70
Fixed carbon.....	39.35	41.91	40.26	40.13	41.64	36.54	37.44
Ash.....	10.09	10.86	12.24	10.15	11.81	18.00	11.50
Sulphur.....	.81	.89	.83	.77	.88	.66	.52
Calories.....	4,984	5,035	5,075		5,097	4,432	4,585
British thermal units.....	8,971	9,064	9,134		9,176	7,978	8,253

a Sampled in 1906 by A. G. Leonard, Bull. U. S. Geol. Survey No. 316, 1907, p. 205.

Only one sample, No. 3701 of the above table, has been tested by ultimate analysis. Its chemical composition after air drying is as follows:

Ultimate analysis of air-dried sample from Weaver bed, Signal Butte.

Ash.....	18.00
Sulphur.....	.66
Hydrogen.....	4.51
Carbon.....	48.01
Nitrogen.....	.65
Oxygen.....	28.17

STEAMING PROPERTIES.

The engineers of the electric-lighting plant and the pumping station of the waterworks at Miles City report that clinkers are apt to form when these coals are burned with forced draft. If plenty of time is given, however, the results are satisfactory, but for this purpose larger furnaces are required than for coals of higher grade. The electric-lighting plant is equipped with two 150-horsepower boilers and common shaker grates without blast. The fire is never allowed to go out, and 4 to 5 tons of coal are consumed in twenty-four hours. Two tons of clean coal from Red Lodge are reported to be equal in efficiency to 3 tons of the local coal, but dirty coal containing much slack, which is sometimes shipped from Red Lodge, is no better than the average Miles City coal.

No samples of Miles City coal have been tested under boilers or with the gas engine by the United States Geological Survey, but such tests of two samples from the Bridger bed in the Red Lodge field, with which these coals are compared by Miles City engineers, are described on pages 174 to 177 of Survey Bulletin No. 332, and a gas-producer test of lignite from Williston, N. Dak., which resembles that from the upper member near Miles City, is described in Bulletin No. 261, page 105. These tests indicate that with the Bridger coal 5.04 pounds as fired are consumed per electric horsepower hour under boilers and 1.80 to 2.34 pounds by the gas producer and gas engine. With the Williston lignite 3.67 pounds as fired are consumed per electric horsepower hour by the gas producer.

DEVELOPMENT.

One of the first attempts to develop the coals of this field was made by the Northern Pacific Company soon after the completion of the railroad, the point selected being near the edge of the right of way at the head of Keogh Flat, 6 or 7 miles above Miles City, where the company located a small mining village called Lignite. Operations here have been suspended for several years, the buildings having been moved away and the openings abandoned. The coal obtained was not suitable for use in locomotives.

At about the same time the Comstock mine, north of Yellowstone River, opposite Miles City, was opened and has been operated unsystematically from year to year. None of the development has been of a permanent character and most of the old drifts have caved in, though it is probable that several thousand tons of coal have been mined here and hauled to Miles City by a roundabout road crossing the river 2 miles above.

The many old openings on coal beds near Signal Butte indicate rather extensive but unsystematic mining there for many years, though in the summer of 1907 all the openings seemed to be abandoned. Similar conditions are to be observed on the left bank of Tongue River, 5 miles above town. In addition to these localities there are many country banks scattered over the field from which ranchmen obtain fuel for domestic use, the prevalent methods of mining such deposits being either by stripping or by undermining the coal in the cut banks of streams.

The Kircher mine, 6 miles northeast of Miles City, is on a somewhat more extensive scale. The coal bed here is 63 feet below the surface and is reached by a slope. The mine is worked by the room and pillar system, the mining being done by shooting off the solid with small charges of powder. Mine cars are pushed by hand to the foot of the slope, up which they are drawn by cable from a horse whim. Ventilation is accomplished by a fire box and mine water is pumped

out by a windmill. During the summer of 1907 five men were employed and the product of the mine was hauled in wagons to Miles City, where most of it was delivered to the electric-light company and steam laundry for \$2.50 and \$2.60 per ton.

Preparations were being made in 1907 for more elaborate operations at the Hedges mine, near the site of the old Comstock mine. The bed, which outcrops about 50 feet above the river, is opened by an incline in order to raise the coal to such an elevation that it can be sent across the river on a cable tramway. When visited late in July the deeper workings of the mine were reported to be filled with carbon dioxide and were not accessible. In this connection it may be noted that explosive gases have not yet been encountered in any of the mines of this field and that safety lamps have not been required at any place.

CONDITION OF THE MARKET.

The coal mined near Miles City competes in the local market with that shipped in from other regions, and more especially with that from Red Lodge, Mont. It commands a lower price than the Red Lodge coal, but during the winter of 1906-7 the supply of the latter was cut off for lack of transportation, and the demand for Miles City coal greatly increased. With the increase of population which the agricultural possibilities of this field warrant, the demand for and use of these fuels near at hand will certainly be very much greater than it is now. Recent experiments have demonstrated that coals of this grade, when converted into producer gas and used in an internal-combustion gas engine, have an efficiency not less than that of the best bituminous coals under steam boilers. None of the Miles City coal has been tested in this way, but should power plants of this kind be successfully installed here the possibilities of usefulness and the value of these coals would be increased many times, and some of the beds now regarded as too impure for mining could probably be worked at a profit.

THE BULL MOUNTAIN COAL FIELD, MONTANA.^a

By L. H. WOOLSEY.

INTRODUCTION.

The preliminary report on the coals of a portion of the Bull Mountain field, Montana, here presented, is based on a detailed survey made during the summer of 1907 by R. W. Richards, H. Bancroft, and the writer. The progress of the work was materially aided by the assistance and hospitality of the residents and of various companies interested in the field, for which acknowledgment can be made only in this general way.

The investigation was undertaken for the purpose of classifying by legal subdivisions of 40-acre tracts the public lands as coal land or noncoal land. The area covered in this manner comprises a strip of country approximately two townships wide, bordering the south side of Musselshell River and extending from the vicinity of Shawmut, Meagher County, to the Bull Mountains. The western and larger part of this area, or that lying roughly between Shawmut and Golden Creek, probably contains no coal of commercial importance. Two thin coal beds were found in the Eagle sandstone near Crawford's coal bank, on Fish Creek, near Cavill's ranch, and elsewhere, but they average only 23 inches in thickness, including a parting of shale 7 to 12 inches thick. The Judith River formation also contains a few thin beds of coal, ranging from 6 to 32 inches, but the beds are commonly lenticular or split by thin partings of shale. No coal beds are known to occur between this formation and the Eagle, above described, and between the former and the coal beds of the Fort Union formation in Bull Mountain no coals of value were observed. Thus, in the hilly country between the lower course of Painted Robe Creek and Golden Creek indications of coal were observed at only five or six horizons, and these beds carried 12 inches or less of coal or coaly shale.

The western part of the country surveyed may therefore be disregarded in a discussion of commercial coal fields. On the other hand,

^a A full report on this coal field is in preparation and will be published as a separate bulletin.

the eastern part, lying roughly east of Golden Creek and including the Bull Mountains, contains a large quantity of coal of commercial value. This area is known as the Bull Mountain coal field, and the purpose of the present paper is to set forth briefly the information gathered in this field.

The first examination of any detail in the Bull Mountain coal field was made by the geologists of the Transcontinental Survey about 1881. At that time Waldemar Lindgren and the late George H. Eldridge examined the stratigraphy and coal beds of this general region, and the results of their studies are briefly given in the Report of the Tenth Census of the United States.^a Two pages illustrated by columnar and cross sections are devoted to a description of the rocks and a discussion of the stratigraphy of the Bull Mountains and surrounding country. Though the authors group all the rocks in the "Laramie series," they describe them in units that correspond fairly well with the Fort Union "somber beds" and Laramie, which were traced and mapped during the last season as separate formations. The coals, which they call black lignites and which are "in every way much superior to the lignites farther east," are described in two pages dealing almost entirely with the Mammoth coal bed. Two plates of sections and 57 proximate analyses of this coal are given. The description of the coal is good, considering its brevity; it brings out carefully the essential facts concerning the extent, character, and thickness of the coal, as well as its general physical appearance. The sections of the Mammoth coal bed are given in detail, but, unfortunately, the locations of many of the sections are too brief for identification. Wherever identification was possible, however, the measurements checked well with those made by the Geological Survey party. The analyses give no calorific determinations, but in other respects they compare very favorably with the analyses given in the present paper. On the whole, therefore, in view of the difficulties under which this early work was carried on, owing to the rough, unsettled condition of the western country at that time, the work seems to have been carefully done, and the report, so far as it goes, may be regarded as generally reliable, except in the identification of the formations. This judgment, however, is based on a study of only about one-fourth of the Bull Mountain field examined by the geologists of the Transcontinental Survey.

LOCATION AND EXTENT.

Practically all of the Bull Mountain coal field lies south of Mussel-shell River, which is roughly its northern boundary, and it extends southward, including Bull Mountains. Its length from north to

^a Eldridge, G. H., *Montana coal fields*: Tenth Census, vol. 15, 1886, pp. 753-755.

south is nearly 25 miles and from east to west 35 or 40 miles, its area being about 750 square miles. The rocks in which the coal beds occur extend as far west as Dean Creek, but the coals thin out in that direction, and hence the area underlain by workable coal beds may be regarded as bounded on the west by the divide between Golden and Wildhorse creeks. The area treated in this report covers about 140 square miles in the southwestern portion of the field, including Tps. 5 and 6 N., Rs. 26 and 27 E., with parts of bordering townships. (See Pl. IV.)

TOPOGRAPHY.

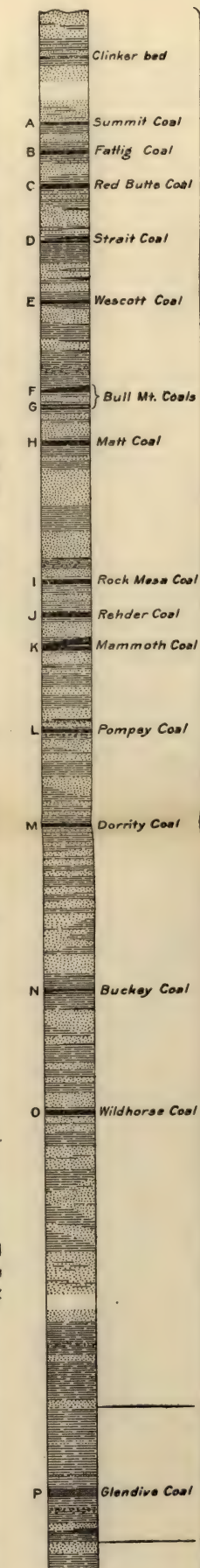
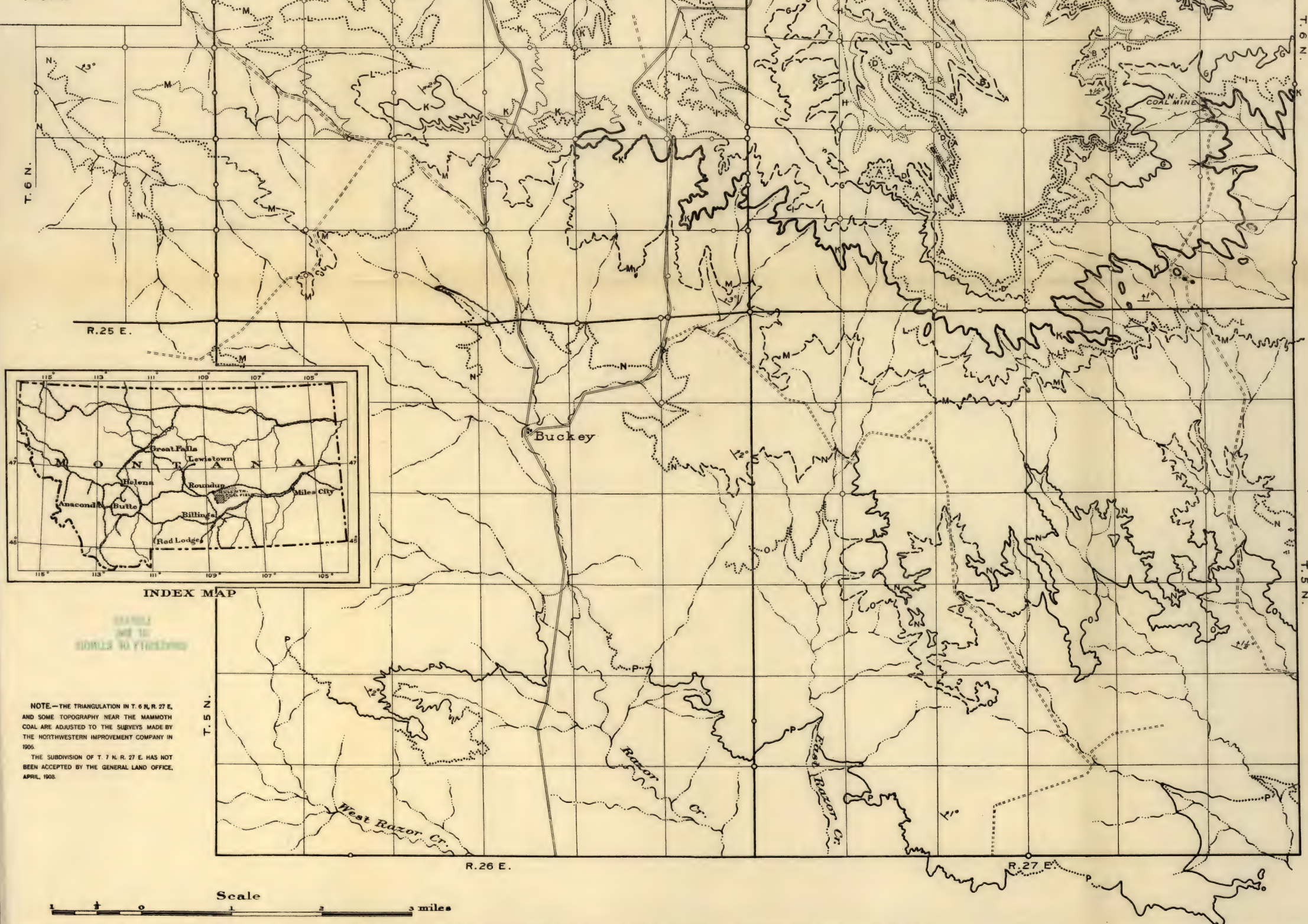
The topography of this field is peculiar and distinct from that of the surrounding country. The divide between Musselshell and Yellowstone rivers extends through the Bull Mountains with a general north of east trend. Prominently rising above the general level of this divide stands an isolated group of flat-topped mesas whose blue bluffs and reddened caps are conspicuous features of the landscape; these are the Bull Mountains proper. To the north and to the south intermittent streams have carved radiating valleys that are canyon-like and sparsely tree clad. North of the mountains the rough country extends to Musselshell River, but on the south it shortly breaks into rolling hills, which extend to the Yellowstone. The mesas of the Bull Mountains consist of arborescent flat-topped ridges whose general axis has a west of north direction. There are three main ridges or mesas, with a few bordering buttes. The southernmost mesa has an extent of nearly 4 miles north and south and about 2 miles east and west. The two irregular mesas which make up the northern part of the mountains have general dimensions of 3 miles from north to south and a similar distance from east to west. These mesas rise from 600 to 700 feet above the surrounding country and attain an altitude of about 4,700 feet above the sea. The effect of the topography on the accessibility of the coals is discussed under "Development," page 75.

GEOLOGY.

Throughout the Bull Mountain field coal of value occurs chiefly in the Fort Union formation. These rocks form the Bull Mountains and the surrounding country for a distance of 6 to 12 miles in three directions—that is, to Musselshell River on the north, Dean Creek on the west, and T. 5 N., inclusive, on the south. Their extent toward the east is not yet known, as that part of the field was not surveyed during the last season. In these rocks coal beds are most numerous in the upper part, that is, in the Bull Mountain mesas, where they occur at intervals of 50 feet or less; in the lower part the intervals are 100 feet or more.

LEGEND

- Coals probably over 5 feet in thickness
 Coals probably 3 to 5 feet in thickness
 Coals probably 2 to 3 feet in thickness
 Coals probably under 2 feet in thickness
 Coals of doubtful thickness
 Main road
 Secondary road
 Corner found
 Dip and strike
 Drift



NOTE.—THE TRIANGULATION IN T. 6 N. R. 27 E. AND SOME TOPOGRAPHY NEAR THE MAMMOTH COAL ARE ADJUSTED TO THE SURVEYS MADE BY THE NORTHWESTERN IMPROVEMENT COMPANY IN 1905.
 THE SUBDIVISION OF T. 7 N. R. 27 E. HAS NOT BEEN ACCEPTED BY THE GENERAL LAND OFFICE, APRIL, 1905.

In this locality the Fort Union formation presents a thickness of 1,400 feet, but this probably does not represent the whole formation, a portion having been removed by erosion, for it reaches a thickness of several thousand feet in neighboring localities, such as the Bighorn Basin on the south. It is composed chiefly of gray to buff sandstone alternating with gray shale. The sandstone, though extremely variable, is commonly massive and evenly distributed throughout the section. The base of the formation is strongly marked by contrast with a band of olive-green clay shale, which belongs to the next lower formation. This shale is well exposed along the Billings-Roundup road, 2 or 3 miles south of Buckey post-office, and may be traced westward across the various branches of Razor Creek, through Fratt's ranch, and down Dean Creek to Musselshell River. Some of the best exposures are found on the east side of Dean Creek, and the same greenish shale may be seen a short distance north of the river at Roundup. In a general way this shale outlines the extent of the rocks bearing important coal beds, though it must not be supposed that everywhere the Fort Union formation contains coal beds of workable dimensions.

A general section of the Fort Union rocks and the underlying olive-green shale given on Pl. IV shows the proportions of sandstone and shale and the relative positions of the various coal beds.

The geologic structure of this region is simple. In general, the rocks lie flat. Careful observations, however, disclose a slight and consistent dip of 1° to 3° in a northeasterly direction on the southwest margin of the field, but this dip flattens toward the mountains and turns northward at their eastern extremity. On the northeast side of the mountains near the head of Fattig Creek, the rocks dip slightly toward the southwest, and near Roundup the dip in this direction is very pronounced. Thus the structure of the field so far as surveyed suggests a gentle syncline plunging slightly toward the northwest.

COAL.

GENERAL STATEMENT.

All the coals in the Bull Mountain field, so far as studied, may be classed as a good grade of subbituminous^a coal ("black lignite"). Most of the coal beds are lenticular in shape, showing a wide variation in thickness at different points on the outcrop. Still, this habit is more common with some coal beds than with others. In general it may be stated that the coal beds appear to thin toward the west, so that beds of considerable thickness in Rs. 26 and 27 E. present little or no coal west of R. 26 E. The average thickness, however, of all the coal beds in the portion of the field studied would probably reach a total of about 35 feet.

^a For the sense in which the term subbituminous is used in this paper see p. 12.

Though the coals occur in lenses, an effort was made to locate and define the workable portions of the coal beds from a study of the outcrop alone. The method of work may be outlined briefly as follows: A careful search was made in coulees and ravines over the whole area for outcrops of the coal beds. All coals thus discovered were traced throughout the area, but only those having a thickness of 2 feet or more were mapped. The ordinary difficulties of mapping presented by the rough country, deeply cut by canyons, were further aggravated by grassed slopes, forested ridge, and slumping talus, which tend to obscure outcrops of the coal. There is a marked difference, however, in this respect between the two sides of the Bull Mountains, the coals being much more obscure on the north side than on the south side, where erosion seems to be more active. Wherever the outcrop was thus covered the horizon was traced by following adjacent rocks. The traverses of the coal outcrops were made by compass and pacing, on foot in rough country and on horseback in open areas, each traverse being tied to section and quarter-section corners. The error in such work was found rarely to exceed 550 feet per mile, and in nearly every case it was within 270 feet per mile. It was impossible to find corner stones at every desired point, especially in townships that were surveyed fifteen or twenty years ago, for the reason that many of the monuments then set have been obliterated by the elements. The map (Pl. IV) shows the number of corners found. It was found that traverses of 3 or 4 miles could be made within a reasonable closing error, which was distributed along the traverse. The traverses of the outcrops of the most important coal beds are plotted on Pl. IV by means of solid, broken, and dotted lines, which represent within certain rough limits the thicknesses of the coal beds and the position of the outcrops with reference to section corners.

DETAILED DESCRIPTIONS.

In this discussion the coals will be taken up in order, beginning with the lowest workable bed and continuing upward to the highest bed in the Bull Mountains proper. Named in this order the coal beds are as follows: Glendive, Wildhorse, Buckey, Dorrity, Pompey, Mammoth, Rehder, Rock Mesa, Matt, Bull Mountain, Wescott, Strait, Red Butte, Fattig, and Summit.

The Glendive coal is of very poor quality, though the bed reaches a general thickness of 3 to 6 feet. It occurs in the southern portions of T. 5 N., Rs. 26 and 27 E. (P coal, Pl. IV), and at one point extends about three-fourths of a mile south of the southern boundary of the latter township. It forms on weathered exposures a conspicuous black band in the soil, which is well shown along the Billings road, about 3 miles south of Buckey post-office. Like many of the higher

coal beds, it thins toward the west, so that in the SW. $\frac{1}{4}$ T. 5 N., R. 26 E., it measures less than 2 feet. A typical section of this bed measured near the southeast corner of T. 5 N., R. 27 E., is as follows:

Section of Glendive coal bed near southeast corner T. 5 N., R. 27 E.

	Ft.	in.
Coal and shale.....	10	
Coal with partings up to one-half inch.....	2	3
Shale.....		2
Coal.....		6
Shale.....		$\frac{1}{2}$
Coal.....	2	
Sandstone.....		$\frac{1}{4}$
Coal.....		2
Shale, brown.....		1
	4	2 $\frac{3}{4}$

As this section shows, partings are numerous and so thin and close together as largely to destroy the value of the coal. This bed has been stripped and certain portions burned with good results, though it is said not to furnish so good a fuel as almost any of the higher beds.

The Wildhorse coal is of much better quality than the Glendive, but its extent is somewhat less. The portion studied lies wholly within T. 5 N., R. 27 E., where it extends roughly across the middle of the township from east to west (O coal, Pl. IV). This coal bed is in the Fort Union formation, at a vertical distance of 450 feet above the Glendive bed. Its average thickness is 35 to 40 inches, and this measurement is surprisingly constant throughout its extent, except in the eastern part of the township, where the bed is only a few inches thick. This is possibly the same bed as that now being mined by the Republic Coal Company on Musselshell River, 2 miles east of Roundup. At this point it is reported to be about 6 feet thick, but in a slope 1 mile to the west the same bed measures 4 feet. A sample taken at the latter point shows that the coal has a fuel value of over 11,000 B. t. u. Owing to the fact that mining in this locality must be carried on down the dip, development is greatly hindered by underground water. The following may be given as a typical section of the Wildhorse coal bed:

Section of Wildhorse coal bed in sec. 24, T. 5 N., R. 27 E.

	Ft.	in.
Coal and shale.....		7
Coal.....	2	11
Shale.....		2
Coal.....		2
	3	10

Above the Wildhorse coal there are one or two thin beds of coal, but the next important bed is the Buckey coal (N coal, Pl. IV), lying

about 140 feet above the Wildhorse bed. This is a very erratic bed, but in places reaches considerable thickness and appears to be of good quality. Its outcrop roughly follows that of the Wildhorse coal, throughout T. 5 N., R. 27 E., lying to the north of that bed. It continues farther west than the Wildhorse, cutting across the northeast corner of T. 5 N., R. 26 E. Near the center of the northern boundary of T. 5 N., R. 26 E., it shows its greatest thickness of more than 6 feet, but within a mile to the southwest it thins to a feather edge. It is extremely irregular in thickness in certain portions of the field, but may be said to average about 3 feet. This coal bed is characterized by one or two partings near the middle, as shown in the following representative section:

Section of Buckey coal bed in sec. 20, T. 5 N., R. 27 E.

	Ft.	in.
Coal.....		6
Coal and shale.....		6
Coal.....	1	1
Shale.....		6
Coal.....	2	4
	4	11

Above the Buckey coal the rocks are practically barren of coal beds for a distance of 200 feet to the Dorrity coal. This is a very persistent bed, uniform both in thickness and quality. It extends throughout Rs. 26 and 27, occurring along the northern border of T. 5 N., R. 27 E., and in the southern part of T. 6 N., R. 26 E. It lies to the south of the outcrop of the Mammoth bed and is about 200 feet below the latter in the stratigraphic column. (See Pl. IV.) The thickness of the Dorrity coal bed ranges between 2 and 3 feet. On the eastern edge of T. 6 N., R. 26 E., like most of the other coals, it thins to less than 2 feet. The following section is representative of this coal bed:

Section of Dorrity coal bed in sec. 36, T. 6 N., R. 26 E.

	Ft.	in.
Coal with bony layers.....		9
Coal.....	1	11
	2	8

Between this coal bed and the Mammoth bed above there are two or more thin beds of coal which in places may reach 2 feet in thickness. The most important of these, the Pompey coal, occurs 110 feet above the Dorrity and is most prominent along the northern border of T. 5 N., R. 27 E., and in the southeast-central part of T. 6 N., R. 26 E. (L coal, Pl. IV). It is, however, very irregular, and in many places its value is utterly destroyed by partings; consequently it does not deserve further description.

The Mammoth bed is the most important coal in the region studied (K coal, Pl. IV), presenting a greater thickness than any other bed.

It is well developed at the southern base of the Bull Mountains proper, in or near the southern and southeastern portions of T. 6 N., R. 27 E. It also extends westward into T. 6 N., R. 26 E., where it crosses the main divide near the center of the township, and is exposed at the point where the Roundup road crosses the summit of the divide. From this point it turns northward, crossing Dorrity Coulee near the northeast corner of this township, sweeping northeastward around the northern group of the Bull Mountains and swinging back into the head of Fattig Creek, in the northeast corner of T. 6 N., R. 27 E. Thence it extends eastward, probably crossing the main divide in R. 28 E. and returning to connect with the outcrop on the south side of the mountains. The eastern portion, however, was not investigated during the last season. Throughout the area studied the coal is of workable thickness except in T. 6 N., R. 26 E. In this locality it is from 3 to 5 feet thick on the main divide in the south-central part of the township, but as the outcrop continues northward the thickness decreases to 2 or 3 feet and probably less. The exposures in this locality were largely concealed by grass and soil so that measurements could not be made, but in fresh cuts the bed measured in places only a few inches. In T. 6 N., R. 27 E., however, the coal has a thickness ranging from 8 to 15 feet, the eastern portion of the township showing usually 15 feet of coal. It is burned at some points, but it is believed that this burning extends only a short distance back from the outcrop where the cover is reasonably thick. The Mammoth bed usually carries three or four thin partings, whose relative position and thickness are shown in the following section, measured at the head of Fattig Creek:

Section of Mammoth coal bed at head of Fattig Creek.

	Ft.	in.
Coal.....	1	10
Shale.....		3
Coal.....	3	10
Coal, shaly.....		2
Coal.....	2	1
Shale and clay.....		6
Shale, coaly.....		6
Coal.....	2	7
Shale.....		2
Coal.....	3	3
	15	2

At a point in sec. 30, T. 6 N., R. 26 E., where this bed measures 8 feet 6 inches, different portions of it were sampled for analysis. The lower 7 feet gave a fuel value of 10,121 B. t. u. in the sample as received, and the upper remaining portion of the bed over 6,200 B. t. u.

The Rehder coal bed (J coal, Pl. IV) is unimportant in the area surveyed. It occurs about 25 feet above the Mammoth bed, from which it is separated by a massive sandstone, and its best development is at the head of Halfbreed Creek, in the northeast corner of T. 6 N., R. 26 E. It is very lenticular, and at this point only does it reach a thickness of more than 2 feet. It is probably nowhere more than 3 feet thick.

About 25 feet above the Rehder coal there is a more persistent bed named the Rock Mesa coal (I coal, Pl. IV). This bed is almost everywhere present, and follows closely the outcrop of the Mammoth bed. It is, however, erratic in that its persistent partings here and there thicken to proportions which destroy the value of the coal bed for commercial purposes. In T. 6 N., R. 26 E., this coal locally develops a thickness between 2 and 3 feet. It attains a like thickness in the southwest corner of T. 6 N., R. 27 E., but from this point eastward the bed is usually less than 2 feet thick. North of the Bull Mountains, however, especially in the northeast corner of T. 6 N., R. 27 E., the bed is remarkably uniform in character and thickness, presenting almost everywhere 2 to 3 feet of good coal. In this vicinity, too, the coal is particularly free from partings, whereas on the southwest side of the mountains partings are more numerous. The following section is typical of the latter locality:

Section of Rock Mesa coal bed in sec. 30, T. 6 N., R. 27 E.

	Ft. in.
Shale, bituminous.....	6
Coal.....	11
Shale.....	2
Coal.....	7
Shale.....	1
Coal.....	8

2 11

For 170 feet above the Rock Mesa coal the rocks are destitute of coal beds of any value, but at this distance appears the Matt coal, which is very persistent throughout the area. On the south side of the mountains its usual position is about 20 or 30 feet above the massive sandstone which skirts the foot of the bluffs. Generally it is less than 2 feet thick, except at the head of Dorrity Coulee, in the northwestern portion of T. 6 N., R. 27 E., where it is best developed on the southeast branches and northeast side of the main coulee. In the former, especially those locally known as Strait and John Matt coulees, it is between 4 and 5 feet thick, though generally the lower measurement prevails. Toward the northwest, along the northeast side of Dorrity Coulee, the coal is thinner, ranging between 2 and 3 feet. This coal bed is generally free from partings, but in places has commonly one thin parting, as shown by the following section:

Section of Matt coal bed in sec. 6, T. 6 N., R. 27 E.

	Ft. in.
Shale, coaly.....	5
Coal.....	2 6
Coal and brown shale.....	5
Coal.....	7
	3 11

At a distance of 45 feet above the Matt coal, and usually separated from it by a bed of sandstone, occur the two Bull Mountain coals (F and G coals, Pl. IV). These beds are very persistent and in general they mark the base of the high bluffs of the southern Bull Mountain mesas. To the northwest, however, a slight dip in the rocks brings the coals down 100 feet or so below the bold bluffs of the northern mesas. These coal beds are usually separated by only 15 or 20 feet of sandstone and a little shale. Accompanying the upper bed and lying upon it is generally a conspicuous dark-gray clay shale 20 to 30 feet thick. In places one or the other of the coal beds is of insignificant size, but generally the remaining bed is of workable thickness. Thus in the southeastern half of T. 6 N., R. 27 E., usually only one of the coal beds measures over 2 feet thick, and this is in most places the lower bed. In the northeastern portion of the township, however, both beds are regular and of workable thickness. In the former locality the thickness ranges from 2 to 5 feet, the average being a trifle over 3 feet. In the northeast corner of the township the upper bed is uniformly 2 or 3 feet thick, and 3½ feet in T. 7 N., R. 27 E. On the other hand, the lower coal approaches 3½ feet in thickness in sec. 14, T. 6 N., R. 27 E., and from this point thins in both directions, being 2 feet or less in T. 7 N., R. 27 E. Partings of shale are not numerous, and the following is, perhaps, a common section in the northeast corner of the township:

Section of Bull Mountain coal bed in sec. 13, T. 6 N., R. 27 E.

	Ft. in.
Coal.....	2
Shale, brown.....	2
Coal.....	2 4
Shale and sandstone.....	12
Coal.....	1 5
Shale.....	3
Coal.....	1 3+
	17 7+

In some localities one or the other of these beds is burned on the outcrop, in which case the horizon is marked by 10 or 12 inches of reddish to gray ashes.

Above the Bull Mountain coal beds the section of rocks presents a series of thin coal beds occurring at intervals of 15 to 40 feet. The Wescott coal (E coal, Pl. IV), about 100 feet above the upper Bull Mountain coal, is the next higher bed to reach significant thickness.

Its irregularity and lenticular form, however, render it of so little value that practically the next important coal above the Bull Mountain coals is the Strait coal (D coal, Pl. IV). This bed averages 200 feet above the lower Bull Mountain coal and always outcrops near the base of the steep slopes of the Bull Mountain mesas. Hence the outcrop of the Strait coal as shown on the map outlines the extent and shape of the mesas. The outcrop of the Strait coal lies within T. 6 N., R. 27 E., except where the northern group of mesas extends beyond the northwest corner of that township. A massive sandstone 30 to 40 feet thick usually overlies this coal and forms a prominent protruding ledge or bench along the bluffs. The Musselshell road, where it crosses the divide between Fattig and Dorrity creeks, passes through a notch in this sandstone and the underlying coal bed, which is exposed on either side of the road. In the southernmost mesa this bed generally measures 2 feet or less in thickness, though at some points, especially in the southern half of the mesa, it is nearly 3 feet thick. Toward the northern mesas the thickness is less, and at their base the coal is generally only a few inches thick. The coal around the northern mesas of the Bull Mountains is not deemed sufficiently important to be represented on the map. An average section of the Strait coal is given below:

Section of Strait coal bed in sec. 32, T. 6 N., R. 27 E.

	Ft. in.
Coal.....	5
Shale.....	1
Coal.....	1 6
Shale.....	1 6
Coal.....	1 6
	5

The lower parting indicated in this section increases eastward from this point to a thickness of 5, 8, and even 15 feet.

Above the massive sandstone which overlies the Strait coal occurs a series of coals, the most important of which are the Red Butte, Fattig, and Summit beds (C, B, and A coals, Pl. IV). These lie 35 or 40 feet apart, the lowest one being 65 feet above the Strait coal. All three, consequently, have the same general extent as the Strait coal, and follow the tops of the main mesas which form the Bull Mountains. One of the thinner coal beds intermediate between the Red Butte and Strait coals presents a thickness of nearly 3 feet in sec. 32, T. 7 N., R. 27 E., but this is probably a local development, as such dimensions were not observed elsewhere. The three coal beds named above do not exceed 3 feet in thickness so far as known. The lowest or Red Butte bed is not well exposed, owing to the heavy talus fringing the steep bluffs of the mountains. Where exposed it measures generally 2 feet or less, and rarely exceeds that figure. The Fattig coal is commonly thicker than the Red Butte bed, measuring between 2 and 3

feet almost everywhere. In the northern part of the main north mesa it is exposed at few places, and hence its thickness here is questionable. The Summit coal is very similar to the Fattig in general thickness, but the distribution of dimensions is different. It presents, roughly, less than 2 feet of coal in the southern portions of the mesas and between 2 and 3 feet in the northern portions. In the northwest mesa, however, it is generally less than 2 feet. These three coal beds are commonly free from thick partings. Their position, however, high up in the mountains makes them the least accessible of all the coal beds of the region surveyed.

Near the crest of the Bull Mountains, and averaging about 70 feet above the Summit coal, or 40 to 60 feet below the tops of the mesas, occurs a mass of clinkers and brecciated rock which has been indurated and reddened for a vertical distance of about 30 feet. This doubtless marks a bed of coal of considerable thickness, which, owing to the thin cover, has been burned through its entire extent.

PHYSICAL CHARACTER.

As already noted, the coals of this region are soft and rather easily reduced to a fine granular mass on exposure to rain and sun. This disintegration is accompanied by the escape of gases, which may be detected for some distance from the outcrop. Though no instances of resulting spontaneous combustion were observed, it is believed that this is perfectly possible and has been the cause of burning of some of the beds. The coals on fresh surfaces present generally a lustrous black appearance. Still, the close observer may detect the bedding by minute alternate layers of dull and lustrous coal. These are seen to best advantage on clean reflecting joint planes. The jointing of the coals in the earlier stages of disintegration results in fragments having a more or less cubical form. As disintegration progresses, however, the cubes tend to break down generally along the bedding into small square plates. Bedding planes, however, are not always, or perhaps even in the majority of cases, the lines of cleavage, but rather the disintegration of the cubes is by conchoidal fracture roughly parallel with the bedding planes. Indeed, the fracture of the coals is markedly conchoidal. If the coals are rubbed against unglazed porcelain the resulting streak is found to be uniformly grayish or blackish brown. They burn with a yellowish flame of moderate length and give off a strong, pungent odor of sulphur. The remaining ash is fine, grayish, and not inclined to be clinkery unless the coals are dirty. Some of the coals contain small globules of amber-colored resin and also small amounts of pyrite. The latter is in places distributed in thin flakes along the joint planes. Even the best coals of the region contain fragments of plants that are still brown and apparently unaffected by the carbonization which the coal beds have undergone.

CHEMICAL CHARACTER.

In order to ascertain the quality of the coals of the Bull Mountain field, an effort was made to collect samples for chemical analysis, but owing to the difficulty of getting fresh exposures few samples of much value were obtained. The samples were collected in a uniform manner and in compliance with specifications used by the fuel-testing plant of the United States Geological Survey, as given on pages 12-13. Analyses of these samples were made by F. M. Stanton in the chemical laboratory at Pittsburg, and the results are given in the following table:

Analyses of coal samples from the Bull Mountain field, Montana.

[F. M. Stanton, chemist in charge.]

Name of coal bed.....		Mammoth.		Wild-horse?	Dorrity.	
Laboratory No.....		a 5797	b 5799	5800	a 5798	a 5801
Sample as received:						
Prox.	Moisture.....	24.59	17.45	12.69	16.95	16.91
	Volatile matter.....	32.86	31.16	28.71	30.78	33.05
	Fixed carbon.....	27.94	45.05	50.90	39.64	39.15
	Ash.....	14.61	6.34	7.70	12.63	10.89
Ult.	Sulphur.....	.41	.49	.54	.49	.34
	Hydrogen.....	4.83	5.45	5.44	.....	.....
	Carbon.....	41.41	59.00	64.26	.....	.....
	Nitrogen.....	.69	.89	.88	.....	.....
	Oxygen.....	38.05	27.83	21.18	.....	.....
	Calories.....	3,449	5,623	6,130	4,776	4,640
	British thermal units.....	6,208	10,121	11,034	8,597	8,352
Loss of moisture on air drying.....		4.30	3.00	2.70	3.20	3.60
Air-dried sample:						
Prox.	Moisture.....	21.20	14.90	10.27	14.20	13.81
	Volatile matter.....	34.34	32.12	29.51	31.80	34.28
	Fixed carbon.....	29.19	46.44	52.31	40.95	40.61
	Ash.....	15.27	6.54	7.91	13.05	11.30
Ult.	Sulphur.....	.43	.50	.56	.51	.35
	Hydrogen.....	4.54	5.28	5.28	.....	.....
	Carbon.....	43.27	60.82	66.04	.....	.....
	Nitrogen.....	.72	.92	.91	.....	.....
	Oxygen.....	35.77	25.94	19.30	.....	.....
	Calories.....	3,604	5,797	6,300	4,934	4,813
	British thermal units.....	6,487	10,434	11,340	8,881	8,664
Thickness of bed.....		<i>Ft. in.</i>	<i>Ft. in.</i>	<i>Feet.</i>	<i>Ft. in.</i>	<i>Feet.</i>
Thickness of part sampled.....		8 6	8 6	4	2 8	2
		1 6	7 0	4	2 8	2

a Badly weathered.

b Slightly weathered.

5797. Upper 18 inches of Mammoth coal bed in NE. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 30, T. 6 N., R. 27 E.

5799. Lower 7 feet of Mammoth coal bed in NE. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 30, T. 6 N., R. 27 E.

5800. Full thickness (4 feet) of Wildhorse (?) coal, 1 mile northeast of Roundup.

5798. Full thickness (2 feet 8 inches) of Dorrity coal in NE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 36, T. 6 N., R. 26 E.

5801. Upper 2 feet of Dorrity coal in NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 27, T. 6 N., R. 26 E.

These analyses differ more widely in British thermal units than perhaps should be expected from coals of the same field having very similar physical characters and occurring under the same conditions. The differences are probably due to the fact that the samples represent different stages in the deterioration of the coals consequent upon their exposure to the deleterious effects of the elements. Strictly fresh samples for analysis were not procurable except from the Wildhorse coal. A sample of this bed was taken from a new opening recently made by the Republic Coal Company, at a point 1 mile north-

east of Roundup and at least one-half mile back from the outcrop of the coal bed. The sample of the Mammoth coal, No. 5799, which ranks next to the Wildhorse in freshness, was taken from the bed beneath a sandstone cover and about 8 feet horizontally back from the outcrop. The Dorrity samples were collected practically on the outcrop of the coal. Hence probably none of the analyses, except that of the Wildhorse coal, represents the true chemical composition and heating value of the coals. It is believed that fresh samples of the other coal beds would approach very closely and probably exceed 10,000 B. t. u. Indeed, a sample from the Mammoth bed comparable in freshness with that of the Wildhorse coal would, with little doubt, reach 11,000 B. t. u. Sample No. 5797, which represents the upper 18 inches of the Mammoth coal bed, has apparently suffered great deterioration from percolating waters, besides being cut by many small partings. To the latter fact may be due a percentage of ash double that of the lower portion of the bed. Both samples were taken along the same vertical line in the Mammoth bed.

An examination of the analyses of air-dried samples, excluding No. 5797, shows that these coals contain an average of 44 per cent of fixed carbon, 32 per cent of volatile matter, 9.7 per cent of ash, and 0.48 per cent of sulphur. The amount of sulphur is considerably less than that of the Great Falls coals, which average 3 per cent. The moisture content is rather large, averaging about 3 per cent, and this has a deleterious effect on the fuel value of the coal. From the association of chemical and physical characters, such as the heating value, which ranges between 10,000 and 12,000 B. t. u.; the disintegration into thin plates on exposure; the brownish streak; the lack of gray, leaden luster; the lack of coking qualities, etc., we may safely conclude that the coals of this field should be classed at least as high-grade subbituminous.

When the analyses are compared with those of coals from Great Falls, Miles City, Red Lodge, Bear Creek, and the Bighorn Basin,^a it may be said that the Bull Mountain coals rank well. Few of the others have a greater fuel value and many have somewhat less.

DEVELOPMENT.

So far as known no extensive mining has been carried on during the last year in the Bull Mountain field. In the area surveyed nothing better than three or four dilapidated coal pits was seen, except the old workings of the Northern Pacific Railway at the head of Railroad Creek, in sec. 24, T. 6 N., R. 27 E. During the last season, however, the projection of the coast extension of the Chicago, Milwaukee and St. Paul Railway along Musselshell River has caused considerable prospecting along that stream, which has resulted in the establishment

^a See papers on these fields in this bulletin.

by the Republic Coal Company of a well-equipped mine 2 miles northeast of Roundup. This company first began to operate during the fall of 1907, and its shaft is probably the first of any considerable size ever excavated in the Bull Mountain field. The company attempted to reach the coal bed through a slope extending beneath Musselshell River, but the coarse character of the beds through which such a slope must extend allowed the entrance of great quantities of water, which was fatal to the project. Thereupon a shaft was sunk on the south side of the river to a depth of more than 100 feet. The coal bed penetrated by the shaft is possibly the Wildhorse, and it is overlain by an excellent roof of heavy sandstone. The floor is clay shale, which may be readily removed if necessary in mining. The coal bed is reported to be over 6 feet thick, and it is said that at the present writing 150 tons of coal are removed daily. Some of the output is put to local uses, but much the larger part is utilized for steam purposes on the new line of railroad.

The further development of this field will be to some extent controlled by the topographic features, the water supply, and the structure of the rocks or lay of the coal beds. The accessibility of the coals depends largely on the topography. The main divide, on which are situated the mesas constituting the Bull Mountains, separates the field into two natural portions—a northern slope toward the Musselshell and a southern slope toward the Yellowstone. Coals outcropping on the south slope are most accessible from that direction, for railroad spurs sufficient to tap the field may be extended from the main line of the Northern Pacific Railway, which is 12 miles from the nearest coal bed. The coals which would thus be mined on the south slope extend through the divide and outcrop on the north slope. This slope has the advantage of a more plentiful water supply and closer proximity to railroad facilities. The coal which is at least 12 miles from the Northern Pacific Railway on the south slope outcrops on the north slope along the line of the Chicago, Milwaukee and St. Paul Railway, and is the one now being mined at Roundup. Furthermore, for the higher coal beds on the north railroad spurs may be projected up the various creeks heading in the Bull Mountains.

Water is notably scarce in some parts of the field. On the south side of the mountains, as already stated, the supply is very scanty during the dry season. On the north side, owing to the general northward dip of the rocks, springs are fairly abundant and water may be had by drilling. It may therefore be necessary in mining some of the coals in this region to use electricity generated at some distant point, possibly along Musselshell or Yellowstone River. This method of mining is probably the only available one for the coals on the south slope, unless, inasmuch as the same beds outcrop on both sides of the mountains, the coal is taken out by mines situated on the north side.

The flow of the ground waters is controlled chiefly by the geologic structure; consequently the northward dip of the coals on the south slope of the mountains accounts, as already suggested, for the scarcity of springs in that portion of the field. Nevertheless, drifts down the dip of the coal beds, even in this locality, would probably fill with water, which would have to be removed by some artificial means. For this purpose the siphon may be used to advantage. On the north slope of the mountains, however, the northerly dip of the rocks would form natural drainage for mines on the upper coals. Indeed, it is believed that coal beds occurring high up in the mesas should be mined chiefly from the north side. The lower coals of the north slope, including the one now mined at Roundup, lie on the northeast limb of the syncline and have a general southerly dip. Hence for mines on these beds a pumping plant is a necessity. Furthermore, the siphon method, owing to the flatness of the country, could not be used so advantageously as on the south slope.

The place at which it would be most economical to locate a mine with a view to natural drainage is the lowest point on the axis of the syncline, which crosses the field between the Bull Mountains and Roundup. A mine so located might work the lower coals up the rise toward the north, east, and south, and thus obtain a natural westerly or northwesterly drainage. The ideal position for such a mine can not be given from the present partial knowledge of the field. Any plan for the development of the whole field along the most economical lines presupposes cooperation among the various operators. For example, a drainage tunnel or a shaft and pumping plant located at the lowest point of the syncline, the expense being borne in common by all operators, might save outlays for the construction and maintenance of pumping plants at each mine.

The geographic position of the coals of the Bull Mountain field, together with their character and relation to those of other fields, shows that there is every likelihood of their increasing development in the near future. The territory to be supplied about the Bull Mountains is not thickly populated, and Billings is the largest town of importance. The towns on Musselshell River, though at present small, will increase in population with the advent of the new trans-continental railroad, but owing to the fact that the agricultural region is naturally restricted by lack of water, it is doubtful if these towns will grow to the size of those on Yellowstone River. Agriculture in this region is largely limited at present to grazing, but the rural population also will no doubt be augmented along the line of railroad. Moreover, irrigation of narrow strips of land along some of the main tributaries of Musselshell River is feasible and will probably be extended in the near future. The resulting increase in population will therefore help enlarge the demand for coal.

COAL NEAR THE CRAZY MOUNTAINS, MONTANA.

By R. W. STONE.

INTRODUCTION.

The belt of sedimentary rocks extending around the north and west sides of the Crazy Mountains in central Montana was examined by the writer in the summer of 1907. This belt has been reported^a to contain several workable coal beds, and the main purpose of the season's work was the investigation of the coal resources, with the idea of determining as accurately as possible their distribution, extent, and value.

The supposed coal belt was mapped from Shawmut westward to the head of Musselshell River and southward to Clyde Park. A large part of this belt is included in the Little Belt Mountains quadrangle and the geology is described in the folio covering that area.^a A topographic map covering 1,000 square miles was completed on the basis of the General Land Office surveys. Streams, highways, and contour lines expressing the relief of the country were drawn with relation to township and section lines. All township and range lines were ridden, and all the section lines in a township running in the same direction, either north and south or east and west, were traversed in the construction of the field maps, which were prepared on a scale of 2 inches to the mile, with a 100-foot contour interval.

Much information regarding the location of coal prospects was obtained from the ranchers. It was found on examining the prospects, however, that there are no coal beds of commercially workable thickness in the area. Coal beds are present and small amounts of coal are taken for domestic use, but all the beds are too thin for mining on a commercial scale. The few ranchers between Shawmut and Summit, on the south side of Musselshell River, who dig an occa-

^a Little Belt Mountains folio (No. 56), Geologic Atlas U. S., U. S. Geol. Survey, 1899.

sional load of coal, get it by stripping beds from 5 to 14 inches thick. In the ridges between Potter Creek and Shields River, 15 miles south-east of Dorsey, there is a bed 3 to 7 feet thick, but clay partings are numerous and crushing has reduced a large part of the coal to slack, so that it is of little value and as yet has not been mined successfully, even on a very small scale. The economic result of the summer's work, then, was to disprove the presence of a coal field in this part of Montana.

The writer was assisted in the mapping by M. I. Goldman, J. H. Cather, and F. D. Morrison.

GEOGRAPHY.

The area here to be described is L-shaped, and lies in Meagher, Sweetgrass, Park, and Gallatin counties. It extends from Shawmut on the east to Dorsey on the west, a distance of 60 miles, and the north-south extent of the western limb of the field is 40 miles. Work was begun at Shawmut, below Harlowton on Musselshell River, and progressed westward between the Crazy Mountains and the river. At the divide between the Missouri and Yellowstone River drainage the course was turned southward down Potter Creek and Shields River to Clyde Park, where the season's work ended.

Relatively, the topography of the area is gentle, being of low relief with but few salient features. It is flanked, however, by mountains several thousand feet high. Aside from the mountain bases the most prominent topographic features are Coffin Butte and Gordon Butte, both of which rise several hundred feet above the surrounding more or less level country. Although some of the streams are deeply incised in their upper courses, the valleys for the most part are open, and it is possible to drive over the greater part of the area regardless of roads. The country is not closely fenced.

Musselshell River is the northern boundary of the area examined as far west as Martinsdale. Fish Creek, American Fork, and Lebo Creek are its principal tributaries from the south. The south fork of Musselshell River, Potter Creek, and a part of Shields River are the main watercourses in the western part of the field. All these streams except Musselshell River can be forded easily.

The region is devoted largely to grazing, and settlement is scanty. Naturally, most of the people live along the main streams or routes of travel. Harlowton, with a population of 500, is the largest village. The Montana Railroad, which runs from Lombard to Lewistown, crosses this area from Dorsey to Harlowton. This line was recently acquired by the Chicago, Milwaukee and St. Paul Railway Company, which has built a new main line up Musselshell River connecting with the old line at Harlowton.

GEOLOGY.

SEDIMENTARY ROCKS.

In his description of this area in the Little Belt Mountains, Weed divides the Cretaceous system into four formations—the Cascade, Yellowstone, Laramie, and Livingston. In recent years the Cretaceous has been further subdivided, and in place of Weed's four formations the writer mapped seven. This division into smaller units is based on lithologic and paleontologic evidence obtained by various geologists and paleontologists in the last few years. The distribution of the Laramie as mapped by Weed suggests that the structure is somewhat irregular, but the results of the work here described show that the structure is still more complex than was supposed. The geology of the area is further complicated by the intrusion of igneous rocks in the form of dikes, sills, and laccoliths. These are most numerous in the vicinity of the Crazy Mountains.

The Cretaceous and Tertiary rocks of this area are divided into nine formations, as follows:

Tertiary.....	{	Fort Union formation.
	{	Livingston formation.
	{	Laramie formation.
	{	Montana group:
		Bearpaw shale.
Cretaceous.....	{	Judith River formation.
	{	Claggett formation.
	{	Eagle sandstone.
	{	Colorado shale.
	{	Kootenai formation.

The lowest rocks of Cretaceous age belong to the Kootenai formation, which has a thickness of 235 feet and is composed of green and red shales in the lower half and brown, gray, and pink sandstones in the upper half. The base of the massive sandstones in the middle of the formation is coarse grained and contains thin layers of quartz and chert pebbles. In some places also the débris from this bed is conspicuous for its numerous slickensided faces and iron staining. Below this conglomerate is a black shale, slightly bituminous, which may be a foot or more thick. It is at this horizon that the workable coal occurs in the Lewistown and Great Falls fields.

The Colorado shale, lying next above the Kootenai, has according to measurements by the writer a thickness of approximately 1,300 feet. It is composed largely of dark shale. The prevailing color is green, although the lower part in places is nearly black. A massive gray sandstone may be present in the lower third of the formation; its thickness varies greatly, ranging up to nearly 200 feet. The upper part of the formation shows transitional stages of deposition from deep to shallow water by the occurrence of numerous beds of sandstone in the shale.

Overlying the Colorado shale is the Montana group, composed of four formations—the Eagle, Claggett, Judith River, and Bearpaw, all of which are of Cretaceous age. The Eagle sandstone, composed very largely of massive gray sandstone, is from 100 to 250 feet thick and presents a marked contrast to the underlying dark Colorado shale. One of the coal horizons of this region is in the Eagle sandstone, but the bed is not of workable thickness. This sandstone is a conspicuous ledge maker and for that reason and because of its whiteness and tendency to weather in stools is easily traced.

The Claggett formation where well exposed produces as a whole a light-brown or tan effect with pronounced ribbing due to thin beds of hard sandstone in the shale that makes up the greater part of the formation. It is a marine and brackish-water deposit and carries abundant invertebrate fossils. Its thickness ranges from 400 to 800 feet. The top member of the Claggett formation is a massive gray sandstone which in many places makes a conspicuous cliff. It closely resembles the massive Eagle sandstone and may be readily mistaken for it.

The Judith River formation, lying next above the Claggett and having about the same range in thickness, is prevailingly sandy. When tilted it forms a low ridge and appears dark gray; where horizontal it tends to weather in badland forms and is banded with light-colored beds. Near the head of Musselshell River the top bed of the Judith River formation is a sandstone which ranges up to 15 feet in thickness and is full of oyster shells; in places, especially around Gordon Butte, the bed is practically a solid mass of shells, 8 feet thick. Seams of coal a few inches thick are known to occur in this formation, which was laid down mainly in fresh water, with an occasional recurrence of brackish conditions. Besides shells it contains fossil bones and wood.

Above this mass of prevailingly fresh-water beds are strata ranging in thickness from 700 to 1,100 feet and composed almost entirely of dark-gray and greenish shale. The color when wet is nearly black, and contrasts strongly with that of the formations above and below. This shale constitutes the upper part of the Montana group and is termed the Bearpaw shale. It is so thick and weathers so readily that where it lies flat it forms an area of very low relief, and where it is tilted a valley is developed in it between ridges of the harder Judith River formation below and the red sandstones above. A feature of some note is the occurrence of limy concretions about a foot in diameter, which are found commonly in the upper part of the formation and which are as a rule highly fossiliferous.

The red and greenish sandstones overlying the Bearpaw shale constitute a distinct lithologic unit, ranging in thickness from 200 to 460 feet, and, although containing some shale members, are

sufficiently sandy and hard to form a conspicuous ridge. This formation is particularly well exposed as a ridge along the western side of T. 5 N., R. 17 E., and crosses Fish Creek at the George Moore ranch. A mile farther north it swings to the west and can be traced readily all the way to Lennep. A peculiarity of this formation is its general reddish color and the occurrence of a layer of red, sandy, cannon-ball nodules near the middle. Its age has not been definitely determined, but lithologically it belongs to the overlying formation and hence it will be provisionally regarded as a part of the Laramie.

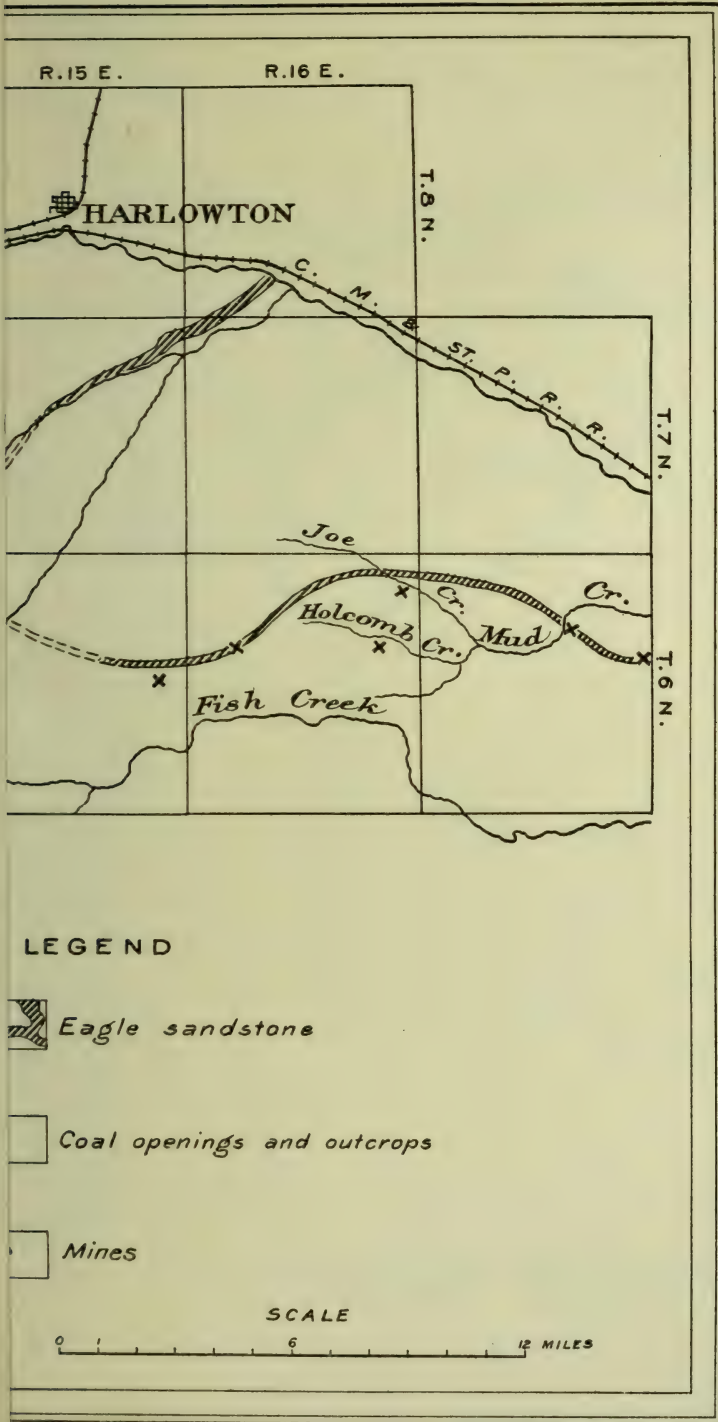
Taken as a whole, the upper part of the Laramie formation is distinguished from the formations above and below by its light-gray color in comparison with their somber hues. It is composed largely of soft gray sandstone and variegated shale. The gray beds, from 1,000 to 2,400 feet thick, make a conspicuous valley across the middle of T. 6 N., Rs. 13 to 16 E. As a whole the formation weathers so readily that it normally forms low country, and for some miles in this area it coincides with the valley of Fish Creek. The gray beds of the Laramie formation are overlain, possibly with unconformity, by somber-colored sandstone and shale which may represent the Livingston formation. Sufficient paleontologic evidence has not been obtained, however, to determine the limits of these stratigraphic units. A section measured by C. A. Fisher and T. W. Stanton on a fork of Big Elk Creek gives a thickness of 5,592 feet from the base of the Laramie to the base of the sandstone and grit of probable Fort Union age, and of 10,324 feet for the beds above the Bearpaw shale. Further field work is necessary before the lithologic and paleontologic distinctions of the Laramie and Livingston formations can be determined.

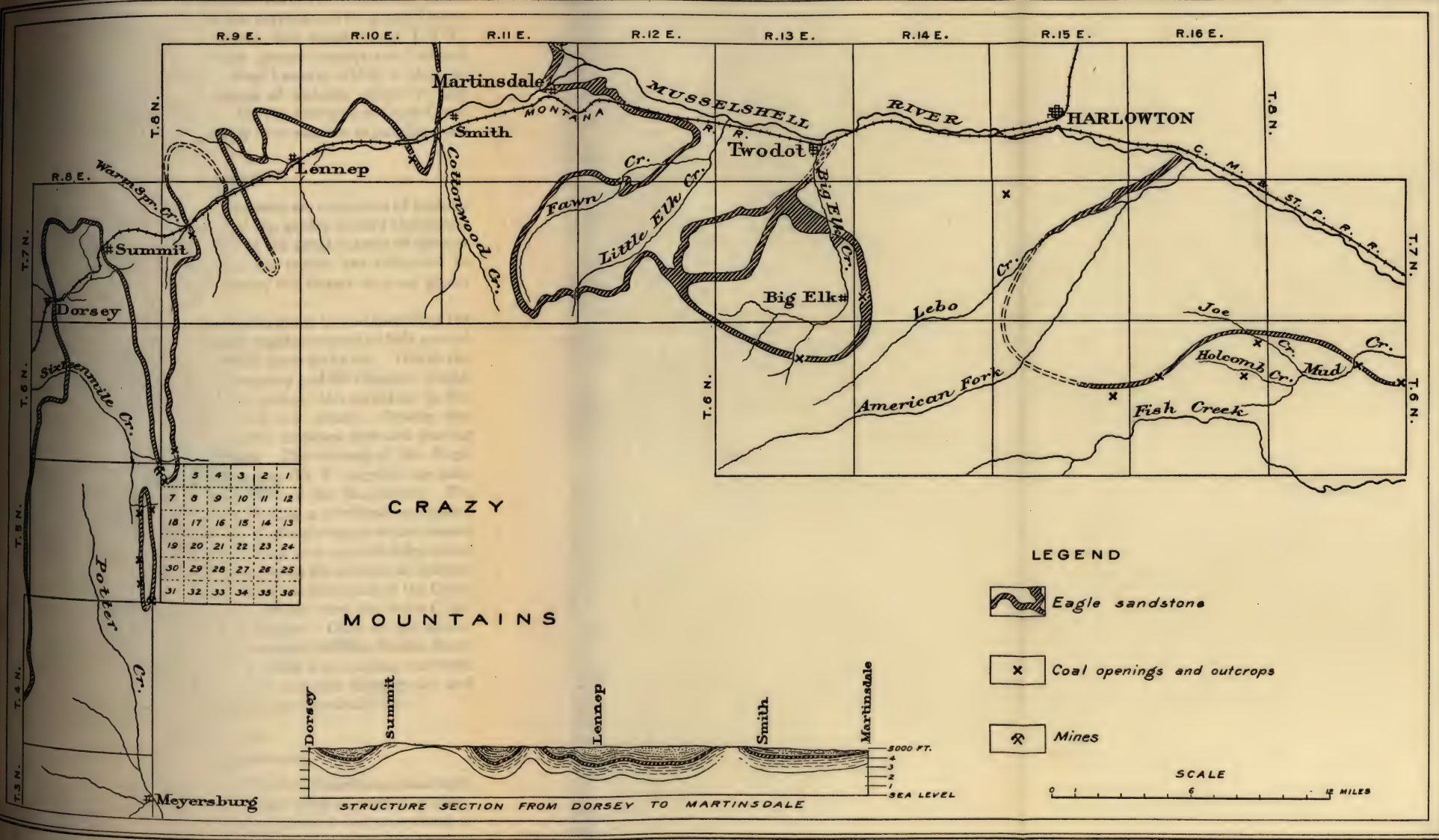
The Fort Union formation, of unknown thickness, but exceeding 4,300 feet, is the youngest in this area. It is composed largely of sandstone, alternating with shale. The base of the formation is a particularly massive, coarse-grained sandstone which forms pronounced wooded ridges. Fort Union beds underlie the southern part of T. 6 N., Rs. 12 to 16 E., and compose the north and east bases, at least, of the Crazy Mountains.

The character, distribution, and thickness of the above-described formations will be discussed much more fully in a report now in preparation by L. H. Woolsey and the writer.

IGNEOUS ROCKS.

Surrounding the Crazy Mountains, which are formed by diorite stocks breaking through a basin of sedimentary rocks, is a zone of igneous intrusions. These occur as dikes, sheets, and laccoliths and were probably injected at the time of the folding to which the rocks of this area have been subjected. The most noticeable occurrences





MAP SHOWING OUTCROP OF THE EAGLE SANDSTONE NEAR THE CRAZY MOUNTAINS, MONTANA.

By R. W. Stone and M. I. Goldman.

are the masses of theralite and theralite porphyry which cap Coffin Butte; the 6,400-foot hill 2 miles to the northeast of it; a small butte 2 miles west of the Miller ranch, on the west range line of T. 7 N., R. 12 E., and Gordon Butte. These igneous masses are believed to be the remnants of laccoliths. Near Lennep, which is close to the Crazy Mountains, dikes and sheets of andesite porphyry and theralite are particularly numerous. On the west side of Comb Creek sheets of igneous rock in upturned shaly beds weather as parallel walls and resemble dikes in appearance.

STRUCTURE.

As mentioned above, the Crazy Mountains are composed of granitic rocks intruded through sediments that dip gently toward the mountains. Coincident with the intrusion of the great masses of igneous material which form the mountains, the region was subjected to strains which produced folds and domes, the former in some places many miles in extent.

The upturned edges of the higher rocks down to and including the Judith River formation describe a fairly regular concentric belt around the base of the mountains, toward which these rocks dip. Out in the valley, where these beds have been worn away and the Claggett, Eagle, and Colorado formations underlie the surface, the structure is less regular, consisting of gentle folds and low domes. Erosion has reduced these forms, cutting away the less resistant beds and leaving the harder ones standing out as ridges. The outcrop of the Eagle sandstone shown on the accompanying map (Pl. V) suggests the complexity of the structure in the upper valley of the Musselshell. The southern half of an eroded anticline having a northeast-southwest axis is indicated by the outcrop of the Eagle sandstone which crosses the river near the mouth of American Fork and again 8 miles below Shawmut. South of Twodot and Martinsdale the structural features are round domes, but farther west, toward the north end of the Crazy Mountains, folds are most pronounced. On the west side of the Crazy Mountains, however, the structure is simpler. Close to the mountains a number of parallel folds form the ridges between Shields River and Potter Creek, but the Potter Creek valley is a syncline, the rocks on the east side dipping west, those on the west side dipping east, and those lying in the middle of the valley being practically flat.

THE COAL.

GENERAL DESCRIPTION.

Although the area included in the Little Belt Mountains quadrangle has been reported^a to contain several coal beds of workable thickness, none was found. Coal has been discovered and prospected at

^a Op. cit.

several points, but nowhere has it proved of sufficient value to develop except in a small area west of the Crazy Mountains, on the head of Sixteenmile Creek, where a bank has been operated for a number of winters but is now idle.

Coal or coaly shale was discovered in the Eagle sandstone at short distances throughout the area examined, but at too few places to determine if it occurs in more than one part of the formation or if it is a continuous bed. The writer believes that the Eagle coal may be absent in many places. In the Judith River formation lenses of coal of short lateral extent and a few inches thick are not uncommon. Beds of similar character are also found in the Laramie and Fort Union formations.

The localities where coal is found in the area here discussed are so few that they can be enumerated and described in detail. Beginning at the east, the first known occurrence is a prospect south of Shawmut, from which Mr. Crawford^a has taken a few loads of coal. It is situated on a small branch of Mud Creek which cuts through ridges of upturned rocks in sec. 13, T. 6 N., R. 17 E. The coal is exposed on the south flank of the northernmost ridge close to the stream and is inclined at an angle of 30°. There are two beds of coal, each less than 1 foot thick and separated by several feet of shale. As the coal makes the flank of the ridge, it can be obtained by stripping a small amount of soil. There is not enough within easy reach, however, to induce near-by ranchers to mine it for regular use. It is subbituminous in character and would be of some value if it had a greater thickness.

Two miles northwest of this locality, in sec. 10, where Mud Creek cuts through the ridges formed by the upturned Eagle and Claggett formations, this same coal bed, or one in relatively the same position, has been exposed on the east side of the creek south of the first ridge. The outcrop of the coal was hidden when the locality was visited, but it is believed to be not over a few inches thick.

On Joe Creek, a branch of Mud Creek, in sec. 1, T. 6 N., R. 16 E., there is a prospect drift in the bluff below a sheep shed which shows a coal bed 28 inches thick. As the bed includes an 18-inch band of bone and very dirty coal, the amount of fuel is not over 10 inches, and therefore it has no value. It lies under a massive sandstone in the lower part of the Judith River formation. On Holcomb Creek, 1 mile south of this locality, the same bed is exposed in the south bank of the stream for a few rods and has a thickness of about 30 inches. It appears to be subbituminous in quality and is variable in thickness, decreasing within a few rods to less than 2 feet.

Where the Eagle sandstone crosses Joe Creek, in sec. 2 of the same township, the presence of coal or coaly shale is shown by fragments

^a Stanton, T. W., and Hatcher, J. B., The geology and paleontology of the Judith River beds: Bull. U. S. Geol. Survey No. 257, 1905, p. 60.

around gopher holes. Three miles farther along the outcrop, in Widdicombe Brothers' 80-acre field in sec. 17, T. 6 N., R. 16 E., a coal bloom was seen at the point where a small gully cuts across the Eagle sandstone south of the road. The coal bed may be at the top of the formation, for three massive sandstones separated by shale and having a thickness of about 216 feet lie below it. It seems to be nothing more than a streak of coaly material, perhaps 6 inches thick. Two miles farther west, in sec. 13, T. 6 N., R. 15 E., a coal bloom was uncovered close to the top of the ridge along which runs an east-west road. The outcrop, which ranges from 26 to 28 inches in thickness, suggests a low-grade, dirty coal, probably subbituminous. As the exposure occurs at the grass roots and the rocks stand at an angle of 50°, the quality of the coal was not definitely determined. Certainly the bed is too thin to be of value, and the steep dip makes it difficult of access. It occurs at the base of the Judith River formation.

Four miles southeast of Harlowton, in the eastern part of sec. 1, T. 7 N., R. 15 E., there is a 5-inch bed of coal in the Eagle sandstone. At Harlowton it was reported that Joseph La Brie stripped several tons of coal on his ranch, in T. 6 N., R. 15 E., in the winter of 1906-7; but on investigation it was found that, although the statement was true, the bed of coal is only 4 inches thick. This coal is in the northwest corner of the township, and is believed to be in the Judith River formation.

A coal bed having a total thickness of 2 feet 2 inches, half a mile east of Big Elk post-office, among the ledges of Eagle sandstone, has been uncovered by Frank Williams. An 8-inch clay parting reduces the amount of coal to 4 inches at the top and 14 inches at the bottom, and takes it out of the class of workable beds. What little coal there is here is subbituminous. Farther down Big Elk Creek, on the Shoemaker ranch, coaly shale has been found in two or three places, but nowhere is it more than 4 or 5 inches thick. It is black sandy shale, with paper-thin laminæ of carbon, and consequently is not combustible. On a branch of Big Elk Creek which flows through a small canyon in sec. 10, T. 6 N., R. 13 E., the Cretaceous beds are well exposed and the Eagle sandstone makes the first ridge, the rocks dipping south at a high angle. In a small coulee on the east, 150 yards from the stream, C. A. Fisher found in the Eagle sandstone a coal bed having a thickness of 7 feet. It is composed, however, of alternating 1 to 3 inch bands of shale and low-grade coal, and hence has no commercial value.

Coal prospects are reported at the north end of the Crazy Mountains, in sec. 21, T. 7 N., R. 10 E., but on investigation they were found to be pits driven on black shale and showing three or four bands of bright coal not over one-half inch thick. These are in the Fort Union formation. The Eagle coal was discovered in the NE. $\frac{1}{4}$

NE. $\frac{1}{4}$ sec. 35, T. 8 N., R. 10 E., a few feet south of the highway, on the bank of a small creek. It lies above a gray sandstone having Eagle characteristics, but is only 3 inches thick. In a small canyon in sec. 23 of the same township, where coal is reported, a foot of black shale was found in the trail on the west bank of the stream. This carbonaceous shale is in the Kootenai formation, and probably represents the horizon of the coal which is mined in the vicinity of Lewistown, Fergus County, and Great Falls, Cascade County.

Prospects at the mouth of Warm Spring Creek, on the south fork of Musselshell River, attract attention because they are close to the road and show black dumps, but on examination it was found that the bed consists of 3 or 4 feet of black shale containing about 1 foot of coal which appears to be of low grade. The rocks at this point stand at an angle of 69° and thus add to the difficulty of obtaining fuel. The coal is believed to be in the Eagle sandstone. Weed says of this locality: ^a

At the mouth of Warm Spring Creek a coal seam has been exposed. The seam is of sufficient thickness and purity to be workable, but the attitude is not favorable, the beds being vertical and the exposure but a few feet above probable water level. The outcropping sandstones can, however, be traced up the slopes southward, and the area will furnish an abundance of fuel when the demand warrants exploitation.

In another place ^b Weed says of the coal on Warm Spring Creek: "A coal seam exposed on the bench land adjoining Warm Springs Creek has been opened at several places, but has so far proved too impure to encourage development."

Reports of the occurrence of coal on Checkerboard Creek, on the north flank of Castle Mountain, 12 miles northwest of Lennep, led to inquiries which resulted in the following information from Postmaster Hull, of Delpine, on the north fork of Musselshell River. Twelve or fifteen years ago a coal bed about 18 (?) inches thick was opened and operated on the head of Checkerboard Creek. The locality is about 4 miles up the creek, three-fourths of a mile above a limestone canyon, 300 yards up a steep drain on the left near the old Castle road. Several hundred tons of coal were taken to White Sulphur Springs for domestic use and proved fairly satisfactory except that the quantity of sulphur contained in the coal gave off fumes that pervaded the town. On account of the high percentage of sulphur, the coal is not good for blacksmithing. Mining was abandoned because of the thinness and poor quality of the coal.

Weed says of this locality: ^c

A thin seam of coal occurring beneath the Dakota quartzite near the forks of Checkerboard Creek has been mined in a small way for Messrs. Spencer, Main & Heitmann, of White Sulphur Springs. The seam is hardly thick enough or the product of sufficiently

^a Weed, W. H., and Pirsson, L. V., *Geology of the Castle Mountain mining district, Montana*: Bull. U. S. Geol. Survey No. 139, 1896, p. 148.

^b *Little Belt Mountains folio* (No. 56), *Geologic Atlas U. S.*, U. S. Geol. Survey, 1899.

^c Bull. U. S. Geol. Survey No. 139, 1896, p. 148.

high grade to warrant working under ordinary circumstances; but owing to the distance of White Sulphur Springs from the railroad the cost of transportation of coal from other points has been prohibitive, and this seam furnished the only available source of supply.

In the Potter Creek valley coal is reported in sec. 17, T. 6 N., R. 8 E., with a thickness of 6 inches. On top of the cliff just west of Harry Blair's house, in sec. 24, T. 4 N., R. 7 E., the Eagle coal has been found, but the thickness is less than 1 foot and the bed is consequently of no value as a source of fuel. Streaks of this sort may be found in the Eagle sandstone on either side of the valley.

The only locality where coal approaching workable thickness has been discovered in the area here described is at the head of Sixteen-mile Creek, in the ridges of folded rocks east of Potter Creek. It was reported by Weed in the Little Belt Mountains folio that a mine had been operated here for several years, a small amount of coal being taken every winter. The mine, which is in sec. 6, T. 5 N., R. 9 E., and is the property of Rees & Bangor, of White Sulphur Springs, was abandoned in 1906. It is south of the road along the creek and is marked by a cabin. As the bed stands at an angle of 35° , a tunnel was driven to undercut it and the coal was taken by drifting and stoping. The drift is about 200 feet long and is open yet, so that the character of the bed can be seen. Portions of the lagging have rotted, however, and caving has begun, so that the mine may soon be closed. The bed ranges in thickness from $2\frac{1}{2}$ feet to $4\frac{1}{2}$ feet. It contains at the top 17 inches of subbituminous coal which is hard and bright and mines in blocks; below this is 1 to 5 inches of plastic clay, underlain by 1 to 3 feet of crushed and dirty coal which makes such fine slack as to be objectionable for steaming purposes. It is said to be a good blacksmithing coal, however. According to John Rees, one of the owners, the comparatively poor quality and the thinness of the solid, black coal and the cost of the long wagon haul necessary to deliver the product at the nearest market make mining unprofitable. From 1883, when this coal was discovered, until the mine was abandoned in 1906 about 500 tons were mined.

Two shafts were sunk to this coal bed at the head of the coulee about one-fourth of a mile south of the above-described mine in 1889, but at a depth of 75 feet the bed decreased in thickness to 6 inches and water came in so copiously that the undertaking was abandoned. These shafts are now caved full. The location of these openings on the crest of a sharp anticlinal fold probably accounts for the disturbed and crushed condition of a portion of the bed, and may in part explain the marked thinning of the coal.

Several other attempts to develop this coal bed have been made along the eastern outcrop on the north side of this fork of Sixteen-mile Creek, but nowhere did the prospecting reveal sufficient coal to induce mining. Only one measurement of the bed was obtained

north of the creek and that was at a point on the west slope of a ridge three-fourths of a mile N. 12° E. from the Rees mine mentioned above.

Section of coal bed on Sixteenmile Creek.

Shale.	Ft. in.
Coal.....	1 9
Shale, brown.....	2 4
Coal.....	3
Clay, sandy.....	2
Coal.....	2
Clay, sandy.....	1
Coal.....	3
Sandstone.	7 9

Although the bed contains over 5 feet of coal, it is so broken and separated by partings as to be economically unworkable, and it stands at so high an angle that it can not readily be developed. The section was measured at the grass roots and so is not very reliable. It is possible that the thick benches of coal at the top and bottom of the section contain small partings or other impurities that make them of little value. Prospecting to some depth is necessary to determine this point.

Development of this same coal bed has been attempted on the head of Cottonwood Fork of Sixteenmile Creek in secs. 12 and 13, T. 5 N., R. 8 E. The outcrop is marked by several small pits, in one of which the bed can be seen now, but the dumps suggest that although coal was found in these prospects it was too thin to mine. Farther south along the same outcrop, in the southwest corner of sec. 24, a slope was driven to cut the coal and a shaft was sunk. The slope is completely closed and the shaft, which is well timbered and covered with a cabin, is partly filled with water. The expense of keeping the shaft free from water was probably the cause of its abandonment.

Still farther south along the outcrop, which is the narrow crest of an anticline, other pits have been dug and abandoned at a depth of a few feet. The composition of the dumps suggests that although a small amount of apparently fair subbituminous coal was found, the value of the bed is greatly affected by carbonaceous-sandstone binders. The coal has been mined and can be seen in the southeast corner of sec. 36, T. 5 N., R. 8 E. At this point, in the stream bank, close under the township standard corner stone, a tunnel was driven west for 140 feet to undercut the coal bed, which dips at an angle of 65° E. Drifts were run for 20 to 40 feet along the coal in both directions, and it is said that about 200 tons was sold, but the bed ranged in thickness from 2 to 3 feet and lay so close to the surface that it showed the effects of surface weathering. The opening is said to have been abandoned because the coal bed pinched out. This statement was not verified, but considering the fact that there is a demand for steaming coal for the traction engines used for plowing and harvesting

in the neighborhood, it seems that some difficulty with the thickness or character of the bed must have stopped the mining. As there is no place in the vicinity where the bed can be undercut at a depth sufficient to get a considerable amount of coal to stope down, and as shafting necessitates pumping, none of the undertakings have been successful.

The coal horizon dips below the surface at the southern line of sec. 36, T. 5 N., R. 8 E., near Ed Potter's home, and there are no other known coal outcrops to the south as far as the survey was carried. Coal is reported at a number of points near Shields, but nowhere did it prove to be more than a mere pocket a few inches in extent.

ANALYSES.

Five samples of the coal in this region were subjected to chemical analysis. All but one were taken according to Survey regulations, the coal being obtained by cutting a groove across the whole thickness of the bed, and excluding partings over one-fourth of an inch thick. The quantity thus obtained was crushed to $\frac{1}{2}$ -inch size and quartered until a 3-pound sample remained. Each sample was sealed in a galvanized-iron can and sent to the chemical laboratory of the United States Geological Survey testing plant at Pittsburg, Pa. Sample 5723 was taken from a bin where it had air dried for eight or ten months. These samples were analyzed under the direction of F. M. Stanton, chemist. The first two samples are from the Judith River formation and the last three from the Eagle sandstone.

Proximate analyses of coal samples from region near the Crazy Mountains.

[F. M. Stanton, chemist in charge.]

Location.....	Joe Creek.	Holcomb Creek.	Big Elk.	Head of Sixteen-mile Creek.	Sec. 36, T. 5 N., R. 8 E.
Section of bed.....	{ Coal...8" Crushed coal...18" Coal...2"	Coal...30"	Coal...4" Clay...8" Coal...14"	Coal...17" Clay...2" Crushed coal...26"	(a)
Part sampled.....	All.	All.	Omitting clay.	Omitting clay.	
Laboratory No.....	5735	b 5732	b 5734	5733	5723
Sample as received:					
Moisture.....	10.37	25.26	29.35	6.69	2.45
Volatile matter.....	22.28	23.51	27.47	25.32	30.83
Fixed carbon.....	32.06	36.68	31.57	35.75	51.75
Ash.....	35.29	14.55	11.61	32.24	14.97
Sulphur.....	.58	.41	.29	.47	.63
Calories.....	4,007	3,546	3,541	4,744	6,854
British thermal units.....	7,213	6,383	6,374	8,539	12,337
Loss of moisture on air drying.....	5.00	13.90	14.00	4.10	.60
Air-dried sample:					
Moisture.....	5.65	13.19	17.85	2.70	1.86
Volatile matter.....	23.45	27.31	31.94	26.40	31.02
Fixed carbon.....	33.75	42.60	36.71	37.28	52.06
Ash.....	37.15	16.90	13.50	33.02	15.06
Sulphur.....	.61	.48	.34	.49	.63
Calories.....	4,218	4,118	4,117	4,947	6,895
British thermal units.....	7,590	6,949	7,411	8,904	12,411

a Coal-bin sample.

b Badly weathered.

The sample from Joe Creek, in sec. 1, T. 6 N., R. 16 E., was cut in the face of the drift about 12 feet from the surface and includes the whole bed, which is 28 inches thick. There are 10 inches of solid coal, separated into two benches by 18 inches of crushed and dirty coal. It is probable that the greater portion of the high percentage of ash shown in the analysis is contained in this crushed portion of the bed. If this part is omitted there is not enough good coal to pay for digging. The same bed was sampled by cleaning the outcrop on the south bank of Holcomb Creek, in sec. 13, T. 6 N., R. 16 E., where for a few rods it has a thickness of 30 inches. The excessive moisture in this analysis is due to the fact that the coal was taken from the outcrop. Aside from the bed being too thin for working, the percentage of ash is objectionably high.

The third sample is from a prospect in the Eagle sandstone at Big Elk. It represents the lower 14-inch bench of a bed which is too small to mine. The high percentage of moisture and ash may be explained in part by the fact that the sample was taken very near the outcrop.

At the head of Sixteenmile Creek a sample was obtained by cutting a groove across the 17-inch upper bench of solid coal and the 26 inches of crushed and dirty coal. The high percentage of ash shown by the analysis is probably contained in this lower part. The exclusion of this lower bench leaves less than $1\frac{1}{2}$ feet of coal, which, although it may be of fair grade, is too thin for exploitation.

The coal-bin sample was intended to represent the character of the coal at the southeast corner of sec. 36, T. 5 N., R. 8 E. Drying for several months under cover has reduced the percentage of moisture, and it is possible that there is less ash than would have been found in a sample cut from the entire thickness of the bed. Although the analysis shows a coal of fair quality, the bed is too thin to mine with profit.

CONCLUSIONS.

The outcrop of the Eagle sandstone shown on the accompanying map (Pl. V), if compared with the geologic maps of the area in Folio 56, will be seen to resemble the outcrop of the Laramie formation. The discrepancy in age determination is due probably to a lack of fossil evidence on the part of the author of the folio, and the difference in mapping to the difference in the degree of refinement in the field work. Weed was mapping the complex igneous and sedimentary geology of a very large area with one assistant, whereas the writer was studying the Cretaceous of only 1,000 square miles with three assistants. Furthermore, the writer had the benefit in the field of the cooperation of T. W. Stanton, F. H. Knowlton, and A. C. Peale in determining the formation limits, and of Stanton, Knowlton, and

Girty's determinations of a large number of collections of fossils. Considering the manner in which the work was done and the paleontologic evidence which supports it, the writer feels that this later work is more nearly correct. This point will be fully discussed in a bulletin now being prepared by R. W. Stone and L. H. Woolsey on the geology of the Musselshell Valley.

In the legend on the maps in Folio 56 Weed describes the Laramie formation (meaning the Eagle sandstone) as "containing several workable coal seams." In the text he says that the coals have rarely been prospected sufficiently to prove either their character or their thickness. On the basis of Weed's statement that the Laramie is coal bearing in this region and on his acceptance of rumors that the beds are workable, maps of the coal areas of Montana for many years have shown a belt of workable coal beds around the west and north sides of the Crazy Mountains and extending southeastward to Billings. The results of the investigation of this area by the writer seem to prove that although coal is present it does not occur in beds thick enough to mine and consequently has not sufficient economic value to warrant classifying the land as coal land.

THE RED LODGE COAL FIELD, MONTANA.

By E. G. WOODRUFF.

INTRODUCTION.

The paper here presented is a preliminary report of a detailed survey of the Red Lodge coal field of Montana.^a This field receives its name from the town of Red Lodge, which was the place of original development of the field and still continues to be the chief mining center. The investigation of this field was made by the writer under the general supervision of C. A. Fisher and with the assistance of J. E. Carman and E. L. De Golyer. The primary purpose of the survey was to determine the amount of land in the area underlain by workable coal and to segregate and classify such land in plats of 40 acres each. In this investigation the method adopted in the field was to traverse each township on the east-west section lines, locating land corners wherever possible. The outcrops of the various coal beds were meandered in order to locate them with respect to section corners, and their thickness was measured at short intervals. The location of the coal outcrops, the sections measured, and the principal mines in the field are shown on Pl. VI.

The first account of this coal field was given by J. E. Wolff ^b in 1886, and later it was described by W. H. Weed ^c and by G. H. Eldridge.^d More recent statements concerning it have been written by L. S. Storrs,^e J. P. Rowe,^f C. A. Fisher,^g and N. H. Darton.^h

LOCATION AND EXTENT.

The Red Lodge coal field is situated at the foot of the Beartooth Mountains, in Carbon County, Mont. It lies northeast of the Yellowstone National Park, between Yellowstone River and Clark Fork, one

^a A detailed report is now in course of preparation, to be issued as a separate bulletin of the United States Geological Survey.

^b Rock Creek coal field: Tenth Census, vol. 15 (report on mining), 1886.

^c Coal fields of Montana: Eng. and Min. Jour., vol. 53, 1892, pp. 520-522.

^d A geological reconnaissance in northwest Wyoming: Bull. U. S. Geol. Survey No. 119, 1894, p. 53.

^e The Rocky Mountain coal fields: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, 1902, pp. 462-463.

^f Montana coal and lignite deposits: Bull. No. 37, Univ. Montana, 1906, p. 23.

^g Development of the Bear Creek coal field, Montana: Bull. U. S. Geol. Survey No. 285, 1906, pp. 269-270.

^h Coals of Carbon County, Mont.: Bull. U. S. Geol. Survey No. 316, 1907, pp. 174-193.

of the main tributaries of the Yellowstone. It extends for a distance of 8 miles from north to south and an equal distance from east to west. About one-half of the area, or 32 square miles, is underlain by workable coal. The beds are known to extend to the northwest beyond Red Lodge, but adjacent to that city they are concealed by material washed down from the mountains. Therefore the western limit of the field as discussed in this report is arbitrarily drawn near that place. Within the coal field there are two centers of production—Red Lodge, a city of 2,000 inhabitants, the terminus of a branch of the Northern Pacific Railway, and Bear Creek, a small coal-mining town on the Yellowstone Park Railroad. These two railroads, which enter the field one from the north and the other from the east, are less than 2 miles apart, but they are separated by topographic features which prevent their connection.

SURFACE FEATURES.

The Red Lodge coal field consists mainly of hilly country, with a few small interstream areas composed of level, gravel-capped terraces in the southwestern part and on both sides of Rock Creek. The rough country in the eastern and central parts of the field consists of deep, narrow valleys between high, irregular ridges and spurs that have a general northeasterly trend. The area is so irregular that it is traversed with difficulty except along the valleys, and even there travel is interrupted at many places by the steepness of the valley sides or the projection of ledges of rock. To the southwest the hilly country merges into a terrace plain which rises gradually to the foothills of the Beartooth Mountains. To the west also rugged topography gives way to a high terrace remnant which forms a narrow divide between the head of Bear Creek and the valley of Rock Creek. West of Rock Creek there is a broad, gravel-covered terrace considerably lower than the one on the east, which slopes gently northward.

Rock Creek, the largest stream of the field, emerges from a mountain canyon 3 miles above Red Lodge and flows northeastward in a valley one-half mile wide bordered by steep bluffs 100 to 200 feet high. It drains that portion of the field west of the high divide; to the east the drainage flows into Bear, Wolf, and Grove creeks. Bear Creek rises in the west-central part of the field and flows northeastward in a depression which is shallow near the mountains, but which rapidly deepens until in the center of the field this stream and its branches occupy narrow valleys 600 to 700 feet below the valley of Rock Creek at Red Lodge. Wolf Creek, the next stream to the south, is similar to Bear Creek, but much smaller. Grove Creek occupies a broad, shallow valley on the southern edge of the coal-bearing area.

Owing chiefly to the topographic features, two separate mining districts have developed in this field. The first development occurred

at Red Lodge, in the Rock Creek valley, along which a railroad found a natural route. This railroad was barred from entry into the Bear Creek area by the high divide east of Rock Creek and by the relative depression of Bear Creek. Previous to the entry of the other railroad into the Bear Creek district development was very slow, for to deliver coal to the railroad at Red Lodge it was necessary to haul it by teams over the divide above described, which materially increased the cost of production. This difficulty has recently been overcome by the construction of the Yellowstone Park Railroad, which enters the Bear Creek area from the east. Reverse conditions are now to be met, however, in the delivery of mine timber from Red Lodge to the Bear Creek district.

GEOLOGY.

STRATIGRAPHY.

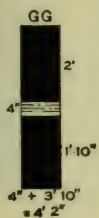
The sedimentary rocks outcropping in the Red Lodge coal field consist mainly of sandstone and shale of the Fort Union formation, which are cut in a few places by igneous intrusions and are covered in the valleys by alluvium and on some of the interstream areas by gravel. The sandstone and shale of this formation comprise a mass of rocks 8,500 feet thick, in which carbonaceous shale and coal beds are intercalated at various horizons. Workable coal beds, however, are confined to a zone above the middle of the section. For the sake of convenience, therefore, in the following discussion the formation is divided into three parts, depending on the presence or absence of workable coal beds: (1) A lower barren member 5,700 feet thick, the lower part of which is not exposed in the field discussed in this report, but outcrops to the northeast in the region between Bear Creek and Bridger; (2) a middle productive member 825 feet thick; and (3) an upper barren member 1,975 feet thick.

The lowest member is composed mostly of yellowish sandstone and shale. Beginning 1,650 feet above the bottom of the formation is a group of beds 1,000 feet thick, composed of varicolored sandy shale with a few beds of soft yellowish sandstone, numerous beds of carbonaceous shale, and in the upper part a few coal beds, one of which contains 18 to 24 inches of coal. Above this group carbonaceous shale and coal beds occur at diminishing intervals as the productive member is approached, but none of these beds is of workable thickness, and they are therefore not given special consideration in this report.

In the middle productive member of the formation the sandstone and shale resemble the sandstone and shale of the lower member and do not seem to indicate any essential difference in conditions of depo-

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SECTION OF COAL BEDS
BELOW NO. 6

T. 7 S.

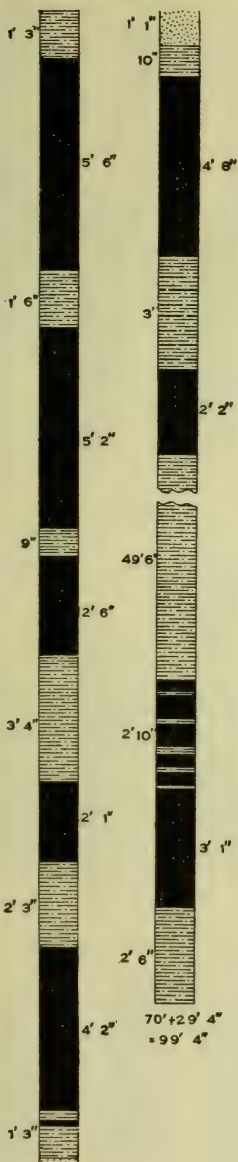


ND

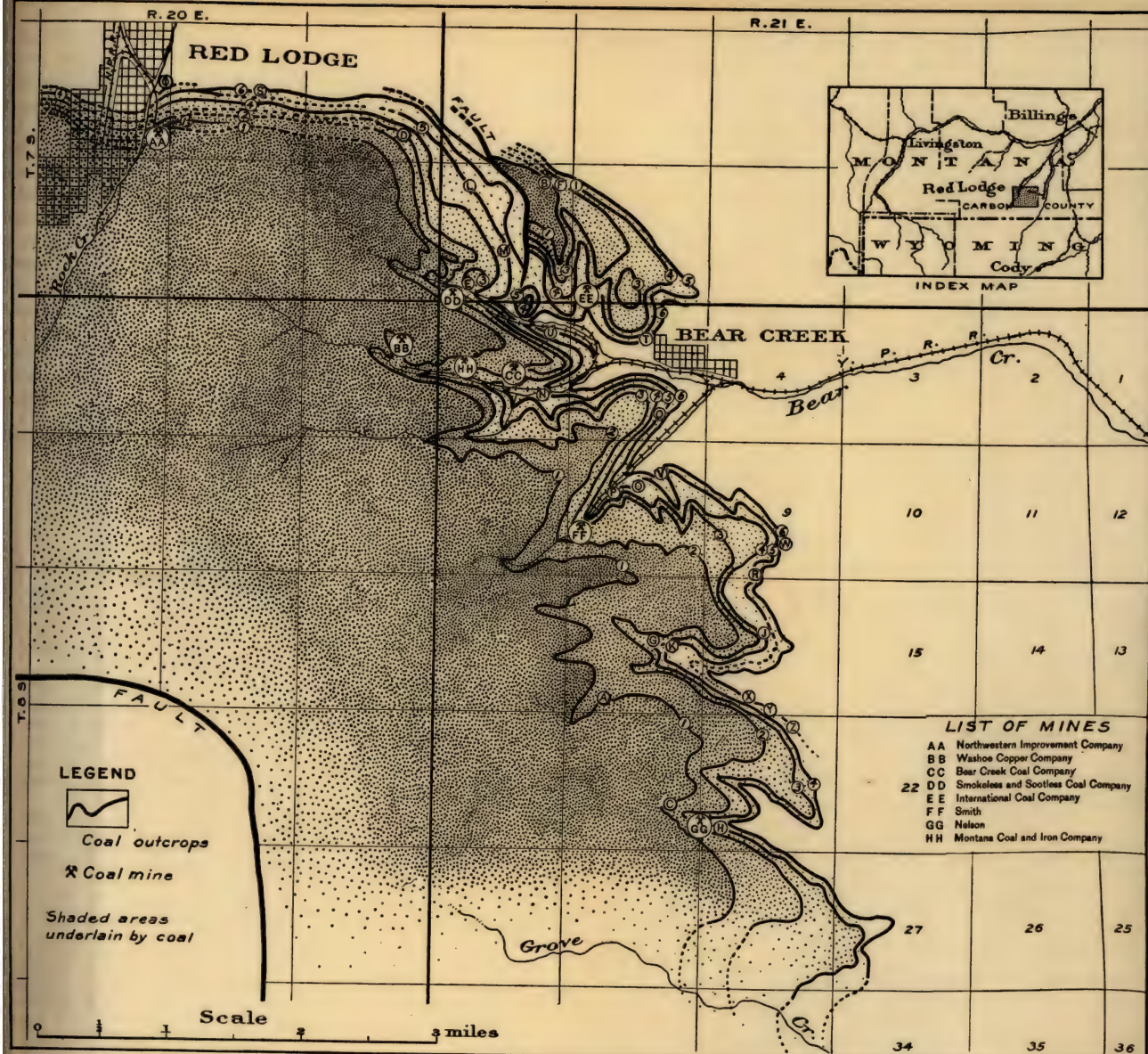


SANDSTONE

of section
ft of section

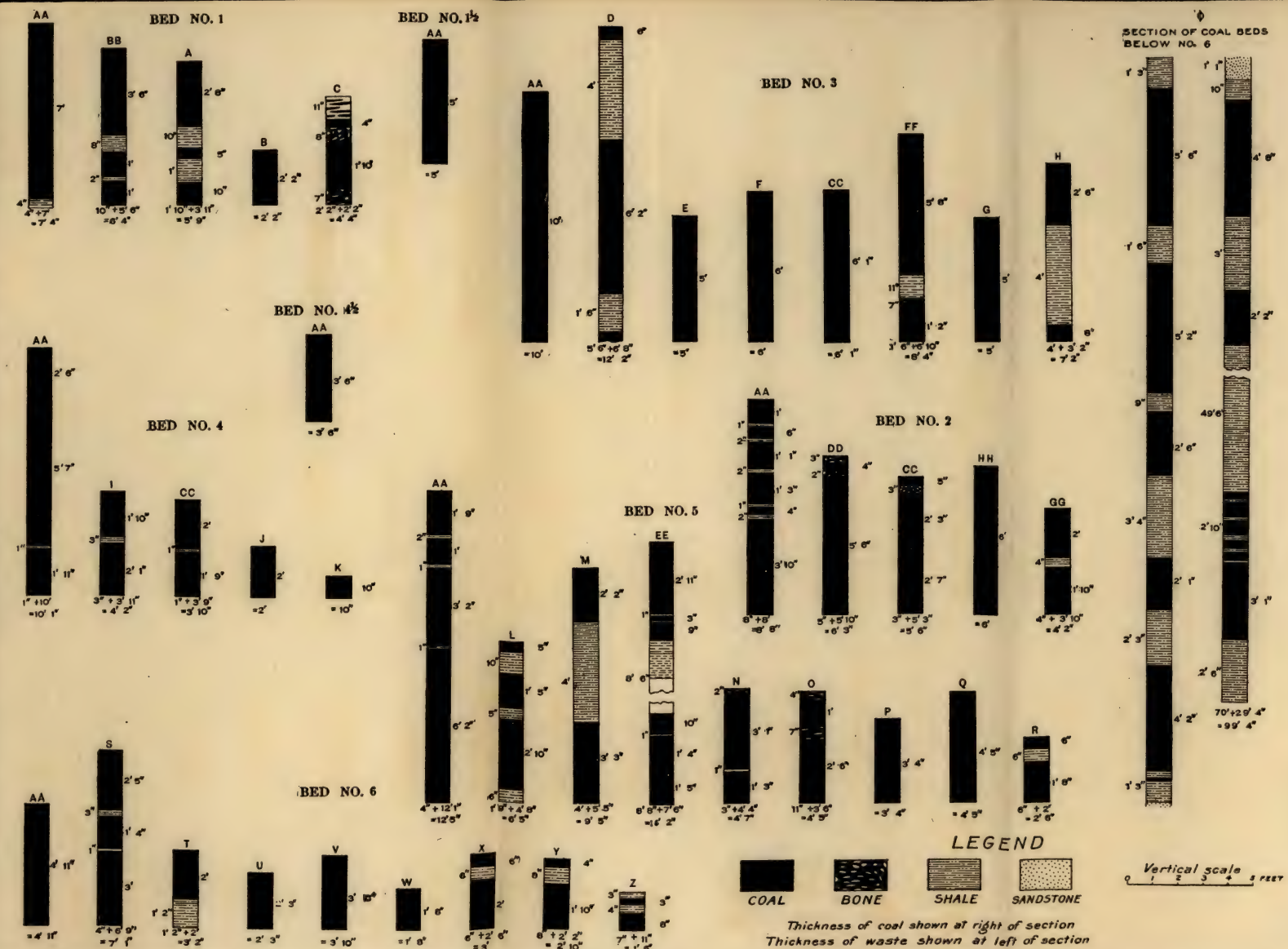


Vertical scale
0 1 2 3 4 5 FEET



LIST OF MINES

- AA Northwestern Improvement Company
 BB Washoe Copper Company
 CC Bear Creek Coal Company
 DD Smokeless and Sootless Coal Company
 EE International Coal Company
 FF Smith
 GG Nelson
 HH Montana Coal and Iron Company



MAP AND SECTIONS OF THE RED LODGE COAL FIELD, MONTANA.

By E. G. Woodruff, J. E. Carman, and D. E. Winchester.

sition, but the carbonaceous shale and workable coal beds intercalated with the other rocks serve to distinguish the member. As indicated above, the coal beds of the middle member do not begin abruptly, but are presaged in the lower member by thin beds of coal. At the upper limit of the middle member, however, there is a sharp transition from the productive measures to the barren beds above.

The coal beds were apparently deposited in basins which are believed to have been shallower toward the southwest, because all the coals thin in that direction or merge into carbonaceous shale, whereas to the northwest the beds thicken to the western limit of the field. The present survey was not sufficiently extended to locate the western boundary of the basins in which the coal was laid down, but the indications are that the thickest deposits are at Red Lodge, or possibly a short distance farther west. A section of the productive member of the Fort Union formation as it is exposed on the east side of Rock Creek at Red Lodge is given below.

Section of coal-bearing beds exposed in east bluff of Rock Creek at Red Lodge, Mont.^a

	Ft.	in.
Shale, yellowish, with layers of tan sandstone.....	22	
Shale, carbonaceous.....	5	
Shale alternating with layers of yellowish sandstone.....	43	
Shale, carbonaceous, with a few thin layers of coal.....	4	
Coal (bed No. 1), not well exposed.....	7+	
Shale, carbonaceous.....	4-6	
Sandstone, tan, and shale, in alternating layers.....	25	
Shale, bluish, with thin layers of rusty sandstone.....	35	
Sandstone, gray, with a few thin shale partings.....	70	
Shale, drab, with union shells.....	1.	6
Coal (bed No. 1½).....	5	
Shale, carbonaceous.....		8
Sandstone, yellowish.....	2	
Shale, sandy.....	17	
Sandstone, yellowish, shaly.....	6	
Sandstone, yellow, massive.....	18	
Shale, bluish, with carbonaceous material at base.....	8	
Coal (bed No. 2), with several thin shaly partings.....	4	7
Shale, sandy, alternating with thin layers of sandstone.....	25	
Sandstone, gray, shaly at top.....	12	
Shale, sandy, alternating with layers of sandstone.....	16	
Coal (bed No. 3), unexposed; thickness in mine.....	10	
Coal, in thin layers, alternating with thick layers of carbonaceous shale.....	12	

^aThis section was measured along the bluff east of Rock Creek by J. E. Carman. The thicknesses of many of the members disagree with those given in the section on page 181 of Bull. U. S. Geol. Survey No. 316. Mr. Darton informs the writer that the latter section was furnished him by Mr. Pettigrew, manager of the Northwestern Improvement Company's mine. As the coal beds vary in thickness from place to place, measurements taken at different points do not agree, and the difference in the thickness of the coal beds in the two sections may be thus explained.

	Ft. in.	
Shale, yellowish, with layers of tan sandstone, more abundant toward the bottom.....	26	
Sandstone, with layers of shale showing on weathered surface. In fresh exposures sandstone is massive; gradual transition to more shaly beds toward base.....	40	
Sandstone, yellowish, shaly.....	5	
Coal (bed No. 4).....	10	
Sandstone, with partings of shale.....	7	
Sandstone and shale, thin bedded, 2 to 4 inches, in alternating layers.....	9	
Sandstone, gray.....	2	
Coal (bed No. 4½).....	5-6	
Shale, yellowish, and rusty sandstone, in alternating layers.....	33	
Shale, bluish, sandy.....	6	
Shale, sandy, and soft sandstone, in alternating layers.....	11	
Shale, bluish, with thin sandy layers.....	25	
Shale, carbonaceous.....	2	6
Coal (beds Nos. 5 and 6), burned out on surface.....	6	
Sandstone, tan, massive.....	22	
Unexposed, probably shale.....	18	
Sandstone, tan, massive.....	10	
Shale and sandstone in alternating layers.....	28	
Shale, bluish.....	15	
Coal (this and the following coal beds are included in No. 7)	5	6
Shale, bluish.....	1	6
Coal.....	5	2
Shale, carbonaceous.....	9	
Coal.....	2	6
Shale, bluish.....	3	4
Coal; contains a 3-inch seam of bone near center.....	2	1
Shale, drab.....	2	3
Coal.....	4	2
Shale, carbonaceous, with a 2-inch seam of coal.....	1	3
Sandstone, gray.....	1	1
Shale, drab, carbonaceous.....	10	
Coal.....	4	8
Shale, carbonaceous.....	3	
Coal.....	2	2
Shale, dark, carbonaceous.....	3	
Sandstone, tan, weathering rusty.....	8	
Shale, blue, unexposed in upper part.....	36	
Shale, carbonaceous.....	2	6
Coal; contains several layers of shale.....	2	10
Coal, good.....	3	1
Shale, brown, carbonaceous.....	2	6
Coal, bony at top; contains several partings.....	1	5
Shale, brown, carbonaceous.....	3	
Sandstone.....	2	
Sandstone and shale in alternating layers, poorly exposed.....	75	
Total coal.....	81+	
Total sandstone and shale.....	814	

The upper barren member of the Fort Union formation is composed, like the lower member, of sandstone and shale, with a very little carbonaceous material. Shale predominates in the lower portion and sandstone in the upper portion. As previously stated, no workable coals are present in this member.

Since the Fort Union sediments were deposited they have been tilted and eroded and in places covered by gravel and alluvium. The terrace deposits, which consist mostly of coarse sand and gravel with boulders here and there, are spread as a thin covering over the older rocks. They conceal the coal on the flat-topped divide between Bear Creek and Red Lodge, and cover the beds on the west side of Rock Creek. The alluvial deposits are confined to the Rock Creek valley, where they cover the coal beds to a slight extent about Red Lodge.

Small dikes cut the sedimentary rocks and outside of the gravel-covered area form low dark-colored ridges extending in a northwest-southeast direction across the field. The rocks composing these dikes have been examined by Albert Johannsen, of the United States Geological Survey, and found to be camptonite. The dikes are so thoroughly disintegrated that they interfere very little with coal mining where they have been encountered. They seem to have caused no displacement of the strata and to have had little metamorphic effect on the surrounding rocks. Where the beds are cut the coal is affected only for a very short distance from the dike, and anthracitization was not observed at any place, though charred coal was found near the contact.

STRUCTURE.

Structurally the rocks form part of an eroded monocline which dips southwestward from the Pryor Mountains to the Beartooth Range, where it is terminated by a fault having a throw of several thousand feet. The dip of the beds, which is 18° at Red Lodge, decreases southeastward to 9° in the western part of the Bear Creek region and to 3° a short distance farther south. Near the southern limit of the field the beds are horizontal. They show minor undulations in many parts of the field, and between the International and the Smokeless and Sootless mines are lifted into a small dome, which is slightly elongated in outline and is less than a quarter of a square mile in area. The beds are steeply tilted on the flanks of the dome and arched sharply over the top. A fault breaks the beds on the northwest side near the south line of the SE. $\frac{1}{4}$ sec. 31, T. 7 S., R. 21 E., and extends irregularly N. 70° W. into sec. 30, where it passes beneath a deposit of gravel. The fault seems to be nearly vertical, with the downthrow on the east. The displacement of the strata on the north side of sec. 31 is between 500 and 600 feet, or sufficient to bring

coal bed No. 1 in contact with coal bed No. 7. The location of the fault and its known extent are shown on Pl. VI, and its effect on the strata is represented in fig. 2. The general structural features from Bridger westward past the International mine to the base of the mountain slope are also shown in the same figure.

THE COAL.

GENERAL CONDITIONS.

The coal field is limited on the south by the gradual thinning and pinching out of the beds, on the east and north by the line of outcrop of the lowest bed, and on the southwest by a great fault along the foot of the mountain slope. Northwest of Red Lodge the beds pass beneath the gravel covering of the terrace and continue westward beyond the boundary of the area surveyed. The workable coals have a vertical range of about 800 feet, as shown by the above section, and are limited both above and below by a thick mass of barren strata. Greater detail of the coal-bearing strata may be obtained by reference to the section.

This section shows a total of 71 feet of coal in beds more than 3 feet thick. From point to point the coal beds differ somewhat in thickness and character, but they are not sufficiently variable to be classed as lenticular deposits. In general the individual beds show a tendency to decrease in thickness from northwest to southeast, a condition which is shown by a comparison of the sections given on Pl. VI. Another general characteristic is the predominance of shale as a roof of the coal, though sandstones are of common occurrence. The sandstone roofs are generally wavy and contain weak domelike areas from 1 to 15 feet in diameter, from which the interior easily falls, rendering mining below dangerous. Very little gas accompanies the coal beds, and water is present only in small quantities except where mining is carried beneath streams. Outcrops of coal beds may be traced continuously throughout

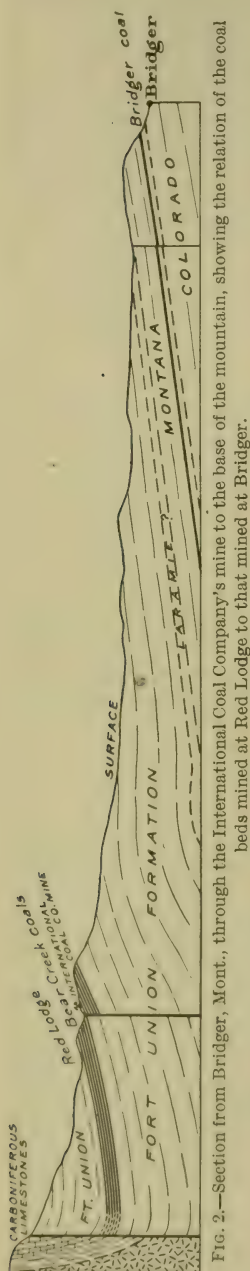


FIG. 2.—Section from Bridger, Mont., through the International Coal Company's mine to the base of the mountain, showing the relation of the coal beds mined at Red Lodge to that mined at Bridger.

the field, except where the edge of the bed is covered for short distances by gravel or talus. The coal beds are easily accessible at

many points, but mines are located only along stream courses, where they can be reached by railroad lines. Stratigraphically the coal beds at Red Lodge and Bear Creek are identical and are not of the same age as the coal bed mined at Bridger and Fromberg, being several thousand feet higher. They are, however, of the same geologic age as the coal of the Bull Mountain field and that mined at Sheridan, Wyo. As first worked at Red Lodge the beds were numbered in consecutive order from the top downward, but since these numbers were established a bed (No. 1½) has been found between 1 and 2 and another bed (No. 4½) between 4 and 5. The numbers of the beds given on Pl. VI correspond to those used in the field. As exposed at Red Lodge bed No. 1 contains 7 feet of coal overlain by carbonaceous shale and underlain by 4 to 6 inches of shale above sandstone. Bed No. 1½ contains 5 feet of bright coal with many thin partings and has a sandstone roof and shale floor. Bed No. 2 contains 8 feet of coal in six benches, with partings of shale one-half to 1 inch thick. It rests upon shale and is covered by sandstone. Bed No. 3 contains 10 feet of dirty coal not worked at present. Bed No. 4 has 10 feet of good coal occurring in three benches, with a parting 1 inch thick 23 inches below the top. This bed is underlain by sandstone and covered by gray shale. Bed No. 4½ is composed of 3½ feet of coal which occurs in several benches and has shale both above and below, rendering mining so difficult that little coal is now taken from this bed. Bed No. 5 contains 12 feet 1 inch of coal in four benches, with partings one-half to 2 inches thick, and lies between beds of hard shale. Bed No. 6 shows 4 feet 11 inches of coal in a single bench, with both roof and floor composed of sandstone. The coal below bed No. 6 is not worked at present and is placed in one group because the interval between the beds is not sufficient to allow any one coal to be mined without disturbing those above.

Mining is generally conducted by the room and pillar system, the size of the rooms and pillars varying according to local conditions. Water is pumped from the mine at Red Lodge and from one mine in the Bear Creek district; the other mines are dry enough for mining but contain sufficient moisture to obviate sprinkling. As gas is present only in small quantities, open lights are used in all the mines. Most of the mines require powder, but in two of them the coal is so jointed that vertical columns may be extracted by undermining and prying down. Mining is done by hand except in the mine of the Bear Creek Coal Company on bed No. 3, where electric machines are also used. About 1,000 miners are now employed in the field, working under the wage scale fixed by the Montana Coal Operators' Association and the United Mine Workers of America in joint convention.

Owing to the peculiar topographic features discussed above the development of this field began on the west side of the divide, around Red Lodge, and has recently been extended to the east side, on the headwaters of Bear Creek and its branches.

RED LODGE DISTRICT.

Coal has been mined in the Red Lodge district for more than twenty-five years. The first mine was opened previous to 1882, but up to 1889 operations were conducted on a small scale. In the latter year the output was 6,000 tons, and it has steadily increased until in 1905 590,035 tons were mined in a working period of 302 days, with 480 men employed inside and 120 outside.^a

The mine at Red Lodge owned by the Northwestern Improvement Company is located on the east side of Rock Creek. The main opening of the mine is in a bluff that rises steeply back of the mine buildings. The underground workings are reached by one main gangway, which extends 2,500 feet down the dip on bed No. 4. Crosscuts lead to the beds above and below and entries extend along the strike. The entries are mostly worked near the main gangways, but one long entry extends $1\frac{1}{2}$ miles to the east and another passes beneath Rock Creek, extending an equal distance to the west. A large number of entries have been opened along the beds, and the adjacent rooms have been worked out, so that now the underground workings cover a considerable area. Coal has been mined from beds Nos. 1, $1\frac{1}{2}$, 2, 3, 4, $4\frac{1}{2}$, 5, 6, and 7, but the main operations have been confined to Nos. 1, 2, and 4.

The mine is well equipped, with electric and mule haulage in the rooms and entries and cable haulage in the main gangway. Water is removed from the mine by a pump operated by electricity, installed at a low point near the bottom of the main gangway, and all the main entries are provided with electric lights. The mine cars are brought from the mine to the tipple, where they are unloaded by rotary dump into a chute which leads to a shaking screen, from which the coal passes to picking tables where the lump coal is assorted for shipment. The lump coal is loaded directly into coal cars or into box cars by a gravity box-car loader, and the screenings are sent to a washer, where the impurities, which consist of shale, bone, and pieces of sandstone, are removed. Steam and electricity are generated by an extensive power plant located near the mouth of the mine.

During the fall of 1907 a new mine was opened and buildings were constructed at the edge of the terrace on the west side of the town. From this mine it is planned to work the various beds to the west. The foundations for a large tipple and other outside buildings have been laid, and when this plant is completed and in operation it

^a McDermott, J. B. Bienn. Rept. Inspector of Coal Mines of Montana, 1905-6.

will materially increase the total coal production of the Red Lodge district.

BEAR CREEK DISTRICT.

General statement.—Five coal companies are operating in the Bear Creek district. They are the Washoe Copper Company, Montana Coal and Iron Company, Bear Creek Coal Company, Smokeless and Sootless Coal Company, and International Coal Company. In addition to the mines of these companies, development for an extensive mine is in progress in Foster Gulch, and a small opening known as the Nelson mine is operated in Taggart Gulch. The location of these mines is shown by the double-letter symbol on Pl. VI.

Washoe Copper Company.—The Washoe Copper Company owns two mines known as No. 1 and No. 2, in the N. $\frac{1}{2}$ sec. 1, T. 8 S., R. 20 E., near Washoe, a post-office recently established between Red Lodge and Bear Creek. Mine No. 1, the larger of the two, is on bed No. 1, which at this mine has a thickness of 6 feet. The beds dip slightly to the southwest and the main gangway extends to the northeast, so that the coal is easily brought to the surface. In February, 1908, the main gangway east had been extended 1,000 feet with 13 rooms, the main gangway north 1,100 feet with two entries and 33 rooms, and the main gangway south 425 feet with 17 rooms. Mine cars are hauled by horses from the mine to the tippie, which is fitted with a tip and screens with bars $1\frac{1}{2}$ inches apart.

During the fall of 1907 mine No. 2 was opened in the valley of Kicking Creek by a double-entry slope 375 feet long on a 30° dip to bed No. 1, where entries were opened, but no mining had been done previous to February, 1908. This mine is equipped with hoisting engine, boilers, etc. According to reports it is the plan of the company to carry the slope to lower beds and operate extensively from this one slope. Pumps are necessary, for water is encountered where the workings extend below the bed of the creek. A force of about 170 men is now employed at both mines, and it is reported that this company has already produced over 15,000 tons of coal for the Butte market.

Montana Coal and Iron Company.—The mine of the Montana Coal and Iron Company is located near the center of the W. $\frac{1}{2}$ sec. 6, T. 8 S., R. 21 E., on a spur of the Yellowstone Park Railroad. It consists of a main gangway and air course 925 feet long, extending toward the northwest. Two entries run east, one only a short distance, the other 550 feet, with 19 rooms. The mine is provided with tippie, box-car loader, shops, and necessary buildings. About 40 miners and 15 outside men are employed. It is reported that 18,000 tons of run-of-mine coal have been sold for domestic and steaming purposes, most of which was shipped to towns along the Northern Pacific Railway.

Bear Creek Coal Company.—The mines of the Bear Creek Coal Company are located on the north side of Bear Creek, $1\frac{1}{2}$ miles west of the mining town of the same name. Beds Nos. 2, 3, and 4 have been opened, and Nos. 2 and 3 are now worked. The conditions for mining these beds are very favorable, because they lie nearly horizontal and carry no water and little gas. In the first entry east on bed No. 3 there is one of the small folds mentioned on page 97, in which the crest rises only a few feet above the level and the steepest limb dips 13° NE. It elevates the coal slightly, but does not interfere materially with mining. The most extensive underground workings are on bed No. 3, where a main gangway has been driven 1,200 feet and three entries and 62 rooms have been opened. Mining is done by hand and by two electric chain machines. Electricity is used to light the main passageways, to propel the haulage motors, and to run the ventilating fans. The mine on bed No. 2 has similar but less extensive development than the one on No. 3. The columnar jointing of bed No. 2, previously described, aids in taking out the coal. The outside equipment of these mines consists of a large tippie, inclined stationary screens, a box-car loader, and an extensive power plant. Tram tracks upon which motor engines are operated connect the tippie with the mines. The output of screened coal from these mines is about 500 tons per day.

Smokeless and Sootless Coal Company.—The mine of the Smokeless and Sootless Coal Company, on bed No. 2, is located near the head of Virtue Creek, on the north side of the Bear Creek district. This mine is now being developed. Two main gangways are being driven, one of which leads to the west and the other to the southwest. A tippie, screens, and a power plant have recently been built near the mouth of the mine, on a spur of the Yellowstone Park Railroad. The coal is undercut by hand and shot down with powder. It is brought to the surface by mule and rope haulage. Columnar structure is exhibited in this mine, but is not of particular service in mining the coal, as it is in other mines in this district, because the jointing is not sufficiently developed to permit the columns to loosen readily. As the coal comes from the mine it is separated into lump and nut sizes. The nut is sold for steaming purposes, and the lump goes to the domestic trade. From this mine the coal is shipped to towns along the Northern Pacific Railway between Billings and Missoula and in northern Idaho. Since the mine was opened, about two years ago, 10,000 tons of coal have been produced. A force of 30 miners and 10 outside men is employed.

International Coal Company.—The mine of the International Coal Company is in the northwestern part of the Bear Creek district, in

the S. $\frac{1}{2}$ secs. 31 and 32, T. 7 S., R. 21 E. The mine, which is on bed No. 5, has one main gangway, with numerous side entries. The room-and-pillar system of mining is commonly used; the long-wall method was tried and proved unsuccessful, because of the bad character of the roof. The coal is mined by bearing in at a small parting 8 inches above the floor and by prying down the columns, which are formed by two sets of intersecting joints. This structure is so well developed that when the beds are worked along the cleat only a small amount of powder is necessary in mining. A tippie is located on a spur of the Yellowstone Park Railroad about 1,000 feet from the mine entrance. An incline, on which the mine cars are operated by gravity, leads from the mine to the tippie. The total production is about 15,000 tons, most of which has been the result of development work. The company employs 50 miners and 10 outside men.

Foster Gulch prospect.—Preliminary development is now in progress in Foster Gulch, which lies southwest of Bear Creek. Two main entries have been opened on bed No. 3, a railroad spur has been constructed, and preparations have been made for a larger plant.

Nelson mine.—The Nelson mine is a small opening on bed No. 2, in Taggart Gulch, $3\frac{1}{2}$ miles south of Bear Creek. This mine is worked by hand to supply coal to neighboring ranches. About 600 tons a year are sold at \$3 per ton.

CHARACTER OF THE COAL.

PHYSICAL PROPERTIES.

The coals in this field have a black color, pitchy luster, and well-developed though irregular joints. They are medium in hardness and relatively free from injurious impurities. They are about as bright in appearance as some of the bituminous coals of Pennsylvania, and, unlike some of the subbituminous coals, do not lose their luster when exposed to the air for a short time.

The coal breaks along smooth joint faces with no pronounced conchoidal fracture. There is an exception, however, in the coal from bed No. 2, which breaks with an irregular surface, giving a granular appearance to fresh fractures very similar to that of some of the coals of West Virginia. In mining the coal breaks into small blocks or columns. In certain beds, as No. 2 in the mine of the Bear Creek Coal Company, the columnar structure is highly developed. In that mine the columns, which are irregular in basal outline, range from 1 inch to 24 inches in diameter and extend across the bench. When taken from the mine they can be piled up like sticks of wood. In general the coal is so well jointed that it can be broken into marketable

sizes with only a small percentage of fine coal or slack. The coals are about equal in hardness to the average subbituminous coals. They are about the same in this respect as the coals mined at Bridger, Mont., harder than those at Sheridan, Wyo., and softer than the bituminous coals of the East. They are indistinctly banded with layers of dull coal. Small accretions of clear brown resin are distributed irregularly through the coal. They appear generally in globular form less than one-fourth inch in diameter, though some exceptionally large ones measure as much as $1\frac{1}{2}$ inches. When broken they appear as brown spots in the black coal.

The coal is free from pyrite nodules, but contains other impurities which produce ash on burning. Dirt occurs as partings too thin to be separated in mining and mixed with coaly matter in thin dull-colored lenses in the good coal. Some of these impurities can be taken out by washing, and in that way coals which are not mined at present could be put on the market. The Red Lodge mine is the only one in the field equipped with a washing plant, and there, as at other mines, it is found to be more economical to leave untouched the beds containing much dirt than to mine and clean the coals before shipment.

According to the classification of coal adopted by the United States Geological Survey, these coals are high-grade subbituminous,^a closely approaching the bituminous class. The coal usually cleaves in small blocks and at some places breaks into prisms, but weathering generally develops the platy structure along the bedding planes. They do not stock well and are therefore placed below the bituminous class, though in heat value they approach some of the bituminous coals of the Mississippi Valley.

CHEMICAL PROPERTIES.

The composition of the coal of the Red Lodge field is shown by the following analyses, made under the direction of F. M. Stanton, of the United States Geological Survey. Samples were taken according to the method described by M. R. Campbell in the introduction to this volume (pp. 12-13). The table shows the analysis of each sample as received and also after air drying. The former represents the coal as it comes from the mine, and the latter more nearly indicates the condition of the coal in the market and as it is burned. For the sake of comparison, therefore, the analyses of the air-dried samples should be used.

^a The name subbituminous has recently been adopted by the United States Geological Survey for the class of coal above the brown lignites and below the bituminous coals—the class generally called "black lignite."

Analyses of coal samples from the Red Lodge field, Montana.

[F. M. Stanton, chemist in charge.]

RED LODGE DISTRICT.^a

Name of coal bed.....	No. 1.	No. 1½.	No. 2.	No. 4.		No. 5.	No. 6.
Laboratory No.....	3590	3592	3588	3595	3591	3593	3594
Sample as received:							
Prox. Moisture.....	11.69	14.07	11.26	11.33	11.22	10.38	10.55
Prox. Volatile matter.....	36.14	33.46	34.08	34.22	36.43	35.98	36.39
Prox. Fixed carbon.....	40.19	42.51	43.26	44.04	45.38	40.62	43.02
Prox. Ash.....	11.98	9.96	11.40	10.41	6.97	13.02	10.04
Ult. Sulphur.....	1.05	2.05	1.14	1.59	.83	1.89	2.23
Ult. Hydrogen.....	5.26						
Ult. Carbon.....	55.46						
Ult. Nitrogen.....	1.20						
Ult. Oxygen.....	25.05						
Calories.....	5,437						
British thermal units.....	9,787						
Loss of moisture on air drying.....	4.70	5.60	4.00	4.40	4.00	4.20	3.90
Air-dried sample:							
Prox. Moisture.....	7.34	8.97	7.56	7.25	7.52	6.45	6.92
Prox. Volatile matter.....	37.92	35.45	35.50	35.79	37.95	37.56	37.87
Prox. Fixed carbon.....	42.17	45.03	45.06	46.07	47.27	42.40	44.76
Prox. Ash.....	12.57	10.55	11.88	10.89	7.26	13.59	10.45
Ult. Sulphur.....	1.10	2.17	1.19	1.66	.86	1.97	2.32
Ult. Hydrogen.....	4.97						
Ult. Carbon.....	58.20						
Ult. Nitrogen.....	1.26						
Ult. Oxygen.....	21.90						
Calories.....	5,705						
British thermal units.....	10,270						

^a All sampled by J. P. Rowe.

BEAR CREEK DISTRICT.

Name of coal bed.....		No. 1.	No. 2.		No. 3.		No. 4.	No. 5.	
Laboratory No.....		a 5821	b 3620	a 5820	c 4008	d 5822	c 4007	d 5823	d 5819
Sample as received:									
Prox.	Moisture.....	8.74	10.05	9.67	9.60	8.60	8.97	9.80	9.31
	Volatile matter.....	34.99	37.22	35.92	36.88	34.52	36.11	34.74	34.14
	Fixed carbon.....	45.72	46.71	46.39	47.10	43.57	43.18	47.19	45.87
	Ash.....	10.55	6.02	8.02	6.42	13.31	11.74	8.27	10.68
	Sulphur.....	2.93	1.44	1.64	2.35	2.78	3.02	2.17	1.99
Ult.	Hydrogen.....	5.49	5.41	5.52		5.05		5.20	5.24
	Carbon.....	59.59	59.64	61.66		56.94		60.20	59.54
	Nitrogen.....	1.24	1.40	1.48		1.43		1.42	1.34
	Oxygen.....	20.20	26.09	21.68		20.49		22.74	21.21
	Calories.....	5,891	6,219	6,018		5,657		6,046	5,818
British thermal units.....		10,604	11,194	10,832		10,183		10,883	10,472
Loss of moisture on air drying.....		2.50	2.00	4.10	2.60	2.50	2.10	3.30	3.40
Analysis of air-dried sample:									
Prox.	Moisture.....	6.40	8.22	5.81	7.19	6.26	7.02	6.72	6.12
	Volatile matter.....	35.89	37.98	37.46	37.86	35.40	36.88	35.93	35.34
	Fixed carbon.....	46.89	47.66	48.37	48.36	44.69	44.11	48.80	47.48
	Ash.....	10.82	6.14	8.36	6.59	13.65	11.99	8.55	11.06
	Sulphur.....	3.01	1.47	1.71	2.41	2.85	3.08	2.24	2.06
Ult.	Hydrogen.....	5.35	5.29	5.28		4.89		5.00	5.03
	Carbon.....	61.12	60.86	64.30		58.40		62.25	61.63
	Nitrogen.....	1.27	1.43	1.54		1.47		1.47	1.39
	Oxygen.....	18.43	24.81	18.81		18.74		20.49	18.83
	Calories.....	6,042	6,346	6,275		5,802		6,252	6,023
British thermal units.....		10,876	11,422	11,295		11,444		11,254	10,841

^a Sampled by J. E. Carman.^b Sampled by J. P. Rowe.^c Sampled by N. H. Darton.^d Sampled by E. G. Woodruff.

A comparison of the analyses in the above table indicates that the Red Lodge coals have more moisture than the Bear Creek coals. It

should be noted, however, in making these comparisons, that the samples are from different parts of one field, and not from beds which occupy different stratigraphic positions. In volatile matter there is only a slight difference between the Red Lodge and the Bear Creek coals. The fixed carbon of the Red Lodge samples is slightly below that of the others in the table. The ash content is about the same in all the samples. In general, the analyses show that the Bear Creek coals are better than the Red Lodge coals, though there is only a slight difference.

The coals of the Red Lodge field contain an average on air-dried samples of 36.8 per cent of volatile matter and 46 per cent of fixed carbon. Sulphur ranges from 0.86 to 3.18 per cent. The amount of ash is rather high. The coal ignites readily and burns freely without fusion. Analyses of coals from adjacent and competing fields are given by other writers in this volume, and by means of these the coals from the Red Lodge field may be compared with other coals entering the same market.

AMOUNT OF COAL AVAILABLE.

Only a general estimate of the amount of coal available in the Red Lodge field can be made, because of the meager knowledge of the beds at places where they are covered. Their condition along the fault at the foot of the mountains is also uncertain. If we consider that none of the coal in the field lies below workable depths, and that the exposures represent the general condition over the field, an approximation may be obtained by assuming that a layer of coal 45.3 feet thick^a is spread evenly over 24 square miles, the area of the productive part of the field, and that the specific gravity of the coal is 1.3. Such an assumption gives 1,238,896,581 short tons. As this enormous tonnage conveys only a vague notion of the amount of coal within the field, perhaps a clearer idea may be obtained by supposing that the coal if placed in a single block would form a body 1 mile square and one-fifth mile high.

MARKETS.

The mines of the Red Lodge field supply coal extensively to the Northern Pacific Railway, to smelters near Butte and Anaconda, and to an extensive domestic trade. The output of the Northwestern Improvement Company's mine at Red Lodge is shipped to points as far east as Bismarck, N. Dak., and west to the Idaho-Washington line. The coals shipped from this field come into competition with the product of several fields in Montana and northern Wyoming, but they are of sufficiently high grade to be successful in the competition.

^a An average of the coal sections measured throughout the field gives 45.3 feet.

In the area over which the coal is distributed there are no extensive coal-consuming plants except the smelters at Butte and Anaconda, hence it is probable that the utilization of the coal will remain as it is now for locomotive fuel, smelting, and domestic purposes. The price at the mine for lump coal averages about \$2.50, but some nut coal is sold as low as \$1 per ton.

FUTURE DEVELOPMENT.

The field described in this report is entering on a period of extensive development, with promise of continued and steady production for many years. The coal lies in a structural basin the form of which as described above probably permits mining under the entire area. It is expected that only a small amount of water and little gas will be encountered. The adjacent mountain slopes are covered by forests which will furnish mine timber for a long period. With the quantity of coal certain and the possibility of extraction assured, the remaining important factor—a field of consumption—is of importance. Domestic consumption is continually being increased by the establishment of many irrigation plants, which aid the growth of population, with an accompanying demand for fuel. The climate of the region is such that fuel for heating is required during the greater part of the year. The coals are best adapted to domestic use. They fire readily, break easily into lump and nut sizes, and are not very sooty. They are good steaming coals, but in locomotives the strong draft forces many of the small unburned particles out of the stacks.

THE LEWISTOWN COAL FIELD, MONTANA.

By W. R. CALVERT.

INTRODUCTION.

The present paper, which is to be considered as a preliminary statement,^a sets forth briefly the results of a detailed survey of the Lewistown coal field made in the summer of 1907 by Eugene Stebinger, J. B. Umpleby, and the writer, under the general supervision of C. A. Fisher. As the primary object of the investigation was the classification of the public lands with respect to coal, the work was conducted with a view of ascertaining the extent of coal areas and their relation to legal land subdivisions. In the central and western parts of the field railroad profiles gave excellent vertical control; in the northeastern part the Geological Survey has run several lines of level and determined many elevations. The accompanying map (Pl. VII) is introduced chiefly to show the relation of the coal outcrop and coal areas to land subdivisions. The detailed information acquired in the course of the work, concerning the geology and coal resources of the region, will appear in the final report.

The Lewistown coal field has not been examined in detail by previous workers. In 1879 Eldridge^b traced the coal outcrop westward from Judith River to Belt Creek, but only brief mention of the coals of the Lewistown field is made in his report. Weed and Pirsson,^c in their report on the Judith Mountains, discuss at some length the coal in the vicinity of that uplift. Various other geologists also have made brief reference to this coal field.

LOCATION AND EXTENT.

The Lewistown coal field, as herein described, comprises not only the limited district near Lewistown, where considerable development has taken place, but also the western extension of that district, connecting with work done the previous year in the Great

^a A full report on this coal field is now in course of preparation, and will appear as a separate publication of the Geological Survey.

^b Eldridge, G. H., *Montana coal fields*; Tenth Census, vol. 15, 1886, pp. 740-757.

^c Weed, W. H., and Pirsson, L. V., *Geological and mineral resources of the Judith Mountains, Montana*; Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 443-621.

Falls areas.^a The territory investigated lies between longitude 109° and 110° 15' W., and the 47th parallel divides it into two nearly equal portions. It is thus located in the center of Montana, including the west-central part of Fergus County and a few square miles of northeastern Meagher County. The greater part of the field lies in the Judith Basin, a name applied to the upper drainage area of Judith River, but it also includes a strip along the headwaters of McDonald Creek and a portion of the Great Plains region lying east of Judith Mountains. The Little Belt and Big Snowy mountains are in the southern part of the field and the Judith and South Moccasin groups lie well within its northern borders. The area as described includes about 1,500 square miles.

TOPOGRAPHY.

The topography of the field is somewhat diversified. In the western half the surface features are essentially those of a plains region, which is but slightly dissected. Judith River and its main tributary from the south, Ross Fork, flow through this district and, with their branches, have accentuated the surface of the structural basin formed by the encircling uplifts of the Little Belt, Big Snowy, Judith, and South Moccasin mountains. The Little Belt Range, bordering the southwestern part of the field, presents a bold northern face, and there is, in consequence, but a narrow transitional zone between plains and mountain topography in that district.

In contrast to the Little Belt Range, the Big Snowy Mountains recede to the north in long slopes which are deeply trenched by streams. This dissected surface is characteristic of much of the eastern part of the field, especially in the vicinity of the connecting ridge between the Big Snowy and Judith mountains, which will be referred to in this report as the McDonald Creek divide. The Judith and Moccasin mountains are fairly rugged and rise rather abruptly from the plains. Higher peaks in the Judith uplift approximate 6,000 feet in altitude; those of the Moccasin Mountains are somewhat lower. The greatest altitude is in the Little Belt Range, where two summits reach 7,400 feet above sea level. The plains range in altitude from 3,600 to 5,000 feet.

In general the topography of the field favors development of the coal, as the streams cut across the coal zone in many localities, allowing access to the outcrop, and the valleys serve as natural routes for transportation. The broad terraces in the western part of the field afford easy routes for railroads, and as a result the Montana Railroad reaches Lewistown from the southwest through Judith Gap with scarcely a cut or fill within the field.

^a Fisher, C. A., The Great Falls coal field, Montana: Bull. U. S. Geol. Survey No. 316, 1907, pp. 161-173.

GEOLOGY.

STRATIGRAPHY.

The rocks of the Lewistown coal field range in age from lower Carboniferous to Quaternary, inclusive. Workable coal in this region occurs at only one horizon, which is near the base of the Kootenai formation, of Lower Cretaceous age. In one locality a thin bed of coal was noted in the Quadrant formation, the upper part of the Carboniferous (?). A lignitic shale also occurs just below the heavy bed of the Eagle sandstone, the lowest member of the Montana group, but it is improbable that either the Quadrant or the Eagle formation will yield coal of workable thickness anywhere within the area described. The succession of the rocks and the relation of the principal coal-bearing beds to strata above and below are shown in the following generalized section:

Generalized section of sedimentary rocks in the Lewistown coal field.

	Feet.
Claggett formation (Upper Cretaceous): White and brown sandstone in lower part and greenish, sandy shale above.	
Eagle sandstone (Upper Cretaceous):	
Shale, dark bluish, containing carbonized wood fragments.....	5
Sandstone, soft, yellowish, cross-bedded, containing iron concretions and woody fragments.....	53
Sandstone, soft, white, usually without bedding.....	170
Sandstone, white, with coaly layer at top.....	10
Colorado shale (Upper Cretaceous):	
Shale, dark gray to black, with a few thin, sandy members....	720
Sandstone, hard, greenish, weathering brown, fine grained, ferruginous.....	3
Shale, dark gray to black, with a hard bed 420 feet above base..	675
Sandstone, grayish brown, thinly bedded, containing an abundance of fish scales (supposed Mowry).....	47
Shale, dark gray to black, alternating hard and soft layers....	890
Sandstone and shale, alternating, brownish in color throughout.	25
Kootenai formation (Lower Cretaceous):	
Shale, maroon, argillaceous.....	200
Sandstone, grayish, coarse grained, cross-bedded.....	8
Shale, maroon, argillaceous.....	60
Sandstone, gray, coarse grained, cross-bedded.....	25
Shale, maroon, argillaceous.....	72
Sandstone, massive, coarse grained to pebbly, weathering soft gray.....	50
Coal and coaly shale	10
Shale and sandstone, alternating; the shale is sandy and the sandstone thinly bedded.....	87
Morrison formation (Jurassic?).	

The above section, being compiled from measurements made in several places in the field, should not be considered as a type of any one locality.

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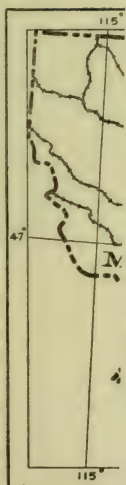
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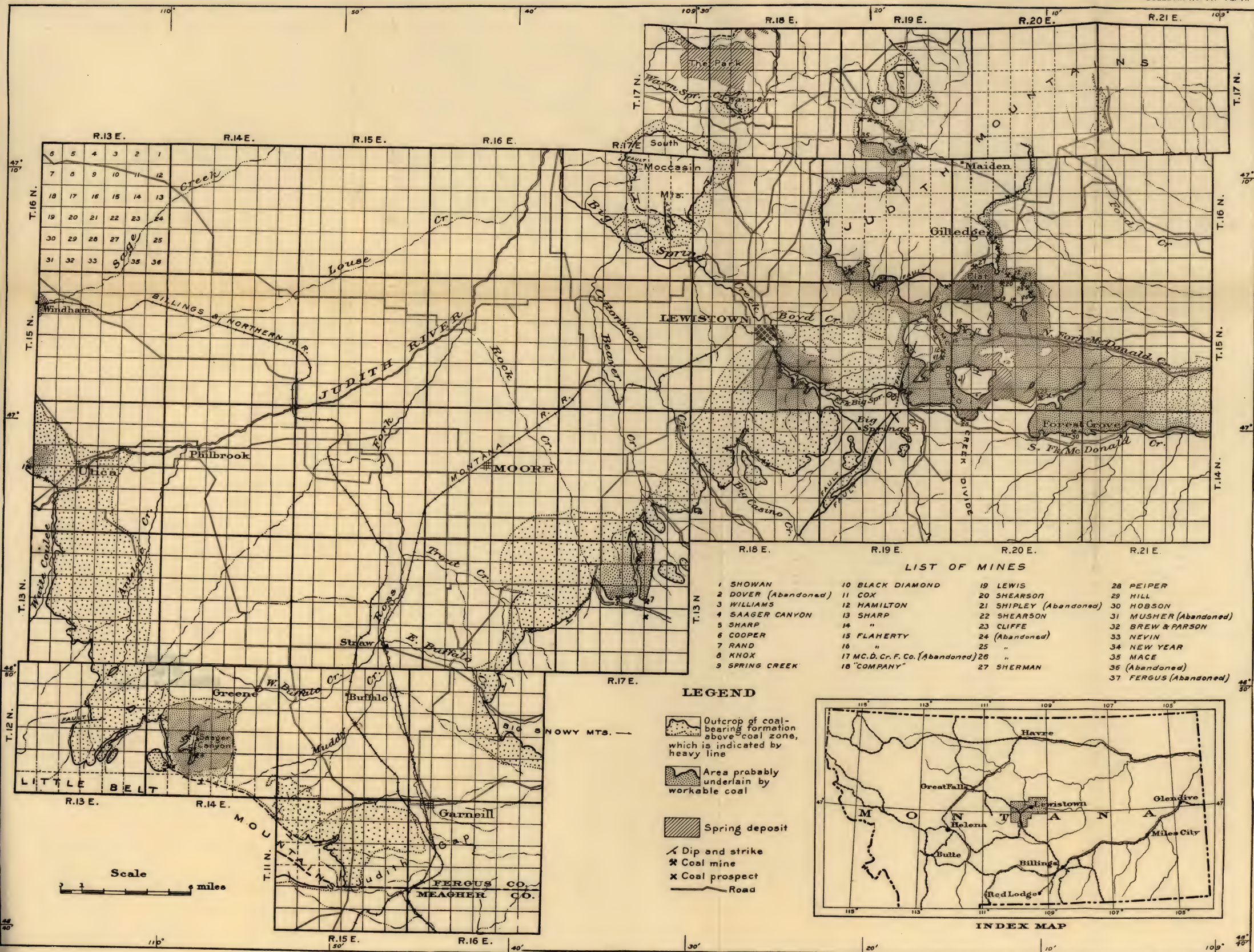
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MAP OF THE LEWISTOWN COAL FIELD, MONTANA.

By W. R. Calvert and E. Stebinger.

The Colorado shale decreases in thickness northward from the Big Snowy Mountains, for a section of that formation to the south of the uplift shows that the interval between the Kootenai red shale and the Eagle sandstone is 2,400 feet, whereas the same interval 15 miles northeast of Lewistown is less than 1,600 feet.

Throughout the field the Kootenai is fairly uniform in thickness, although the individual members comprising the formation vary locally. As a formation it is readily distinguished by the bright, maroon-colored shales and by the coarsely cross-bedded sandstone just above the coal. This sandstone in many places produces marked topographic features, standing out in bold ridges, which are usually timbered with pines. So characteristic is the association of pines and other vegetation with this sandstone, especially where it is exposed over a considerable area, that the growth serves as a valuable guide in the search for coal.

In the vicinity of the Moccasin Mountains and to the south of the Judith uplift, along the McDonald Creek divide, certain areas are overlain by a massive white limestone from 50 to 250 feet thick, which locally resembles the upper member of the Madison limestone. Its structural relations, however, as well as the character of the rock, preclude the possibility that it belongs to the Carboniferous system; it represents instead remnants of a formerly extensive hot-spring deposit. The fact that hitherto it has been considered as Madison limestone has delayed to some extent the development of coal in certain localities. This is especially true with reference to Flat Mountain, the southernmost extension of the Judith uplift, where it was believed that the coal bed would be cut off by the limestone within a short distance from the outcrop. Wherever the spring deposit overlies the coal-bearing formation, however, there seems no reason to conclude that mining conditions are rendered especially unfavorable thereby.

STRUCTURE.

MAJOR FEATURES.

The structure in the western part of the Lewistown coal field is relatively simple, the beds dipping at a slight angle away from the Little Belt and Big Snowy mountains. In general this relation prevails throughout the area west of Judith River and Ross Fork up to the very base of the Little Belt Range, where the strata stand practically vertical or even dip at a high angle to the south. The structure of the east end of this range, therefore, is that of an anticline overturned to the north. The Big Snowy Mountains are also anticlinal in structure and are apparently slightly overturned to the south near their west end. North of these mountains the strata in general dip away from the uplift at a low angle. The ends of the

Little Belt and Big Snowy anticlines extend somewhat past each other and are connected across Judith Gap by a sharply folded anticline with curving axis.

In contrast with the ranges above described the Judith and Moccasin mountains present quite different structural features, being laccolithic in type. Erosion has removed the softer Mesozoic strata from these uplifts, exposing Paleozoic or igneous rocks, and as a result the coal-bearing rocks encircle them, the continuity of the coal outcrop being broken here and there by irregular igneous masses.

MINOR FEATURES.

Folds.—In addition to the large folds of the Little Belt and Big Snowy ranges, numerous smaller folds are developed in their vicinity, one of which is cut through by Saager Canyon. Near Judith Gap there has been considerable folding, the convolutions usually not influencing the topography to any great extent. In the district southeast of Lewistown minor folds also occur.

Faults.—Ten faults of considerable magnitude were noted in the field. The most disturbed district is between the forks of Big Spring Creek in T. 14 N., R. 19 E., where a block fault about 6 miles long, trending northeast-southwest, ends suddenly in sec. 3 in an anticline with its axis at right angles to the line of fault. To the west the faults run together near the southern limits of the field in sec. 36, T. 14 N., R. 18 E. The block is about half a mile wide. A third fault also ends near the anticline above mentioned and extends northeastward to sec. 23, T. 15 N., R. 19 E. Several faults occur in the vicinity of the Moccasin Mountains, and one of considerable length crosses Deer Creek in T. 17 N., R. 19 E. A rather unusual fault occurs near the south end of the Judith Mountains, and is known as the Kelly Hill fault.^a It is about 2 miles long, is curving, with the convexity toward the north, and has a maximum displacement of nearly 1,000 feet. The fault scarp, of Madison limestone, is a prominent feature as viewed from the Lewistown-Giltedge stage road. Only one fault of the thrust type was encountered in the field. It occurs in sec. 15, T. 12 N., R. 13 E., is about 2 miles in length, trends almost east and west, and to the east is finally lost in the Saager Canyon anticline. A rather peculiar feature in connection with the faults described is that in almost every one the displacement is about 300 feet. None of these faults affect areas of workable coal, although in certain localities minor displacements have been encountered in underground workings.

Domes.—In the eastern part of the field domes are of common occurrence. The locality of most pronounced doming is south of

^a Weed, W. H., and Pirsson, L. V., *Geology and mineral resources of the Judith Mountains of Montana*: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, p. 499.

the Judith Mountains, although there is another similar area in T. 17 N., R. 19 E. These domes are believed to be small laccoliths, and are probably related in some way with the main igneous mass of the Judith uplift. As they are in an area of workable coal they are of considerable importance, viewed from the standpoint of the coal miner. All the domes are cut across by streams and the coal bed is thus exposed near the periphery. Although several square miles of coal have been removed by the dissection of these minor uplifts, yet the domes are a beneficial factor in mining, as they bring the coal into a favorable attitude for working.

THE COAL.

DISTRIBUTION.

Although coal-bearing rocks of the Kootenai formation outcrop over a large part of the Lewistown field, and in general underlie the entire region, the coal is not continuous throughout the area. A feature noted in the Great Falls field to the west is that the coal occurs in limited districts with unproductive areas between, and it was seen early in the season that the Kootenai coal has the same habit to the east. For convenience the several coal areas of the Lewistown field will be discussed as separate units—termed the Sage Creek, Buffalo Creek, Rock Creek, Warm Spring Creek, and McDonald Creek districts. The location and approximate extent of these districts are shown in Pl. VII.

DESCRIPTION OF COAL DISTRICTS.

SAGE CREEK DISTRICT.

General conditions.—The Sage Creek district has been described in a previous report^a as lying mainly in Tps. 15 and 16 N., Rs. 11 and 12 E., but including portions of Tps. 15 and 16 N., R. 13 E. The latter two townships were included in the area investigated the last season, and hence are mapped as a portion of the Lewistown field, though coal does not show in outcrop within them, and even on their extreme western edge it probably lies at least 500 feet beneath the surface. At this locality the beds dip to the east at a moderately low angle, so that within a short distance the coal passes beyond a depth at which it can be mined economically under present conditions. Although it is not probable that the coal mined near Utica, in sec. 24, T. 14 N., R. 13 E., is properly to be considered as belonging in the Sage Creek district, it is tentatively included as such. The extent of this portion of the district is limited to only a square mile or so northwest of Utica, for to the south the coal thins rapidly, and to the east it is carried to great depths by dips in that direction.

^a Fisher, C. A., The Great Falls coal field, Montana: Bull. U. S. Geol. Survey No. 316, 1907. pp. 161-173.

As exposed near Utica the coal outcrop shows that there are three coal beds about equally separated in a vertical range of 35 feet, the middle bed being the only one in which workable coal occurs. A section of this middle coal bed is as follows:

<i>Section of middle coal bed at Utica, Mont.</i>		
Shale.		Ft. in.
Coal.....	1	6
Shale, carbonaceous.....	1	3
Coal, impure.....		8
Shale.....		10
Coal, upper 6 inches bony.....	2	2
Shale.		
		6 5

The coal of both lower and upper benches is soft and slacks readily on exposure to the air. Small nodules and lenses of iron sulphide are present in the coal.

Development.—There is only one mine in the part of the district here considered. This is owned and operated by M. A. and H. A. Showan. The mine was first opened about twenty years ago, and coal was taken out desultorily for several years; the mine was then abandoned, and finally reopened by the Showans in the fall of 1906. Only a small amount of coal is mined for local use, the greater part of the fuel supply for Utica and vicinity coming from the Sage Creek mines to the northwest.

BUFFALO CREEK DISTRICT.

General conditions.—The Buffalo Creek coal district is situated in T. 12 N., R. 14 E., and includes the area between Buffalo Creek and the Little Belt Mountains along either side of Saager Canyon. The district is limited on the south by the coal outcrop which lies along the base of the Little Belt Range, and along Buffalo Creek steep dips carry the coal too deep for practical working; west of Saager Canyon the coal thins, and to the east it is deeply covered by overlying formations.

The workable coal in this district ranges from 30 to 48 inches in thickness. It is underlain by sandstone and overlain by dark bone. Forty feet above this bed occurs another coal which, although of good quality, is too thin to work.

Development.—At present two small mines are in operation in Buffalo Creek district, both in Saager Canyon. One, known as the Williams mine, located in the NE. $\frac{1}{4}$ sec. 20, was opened in the fall of 1906, and the other, which has been opened recently, is situated in the NW. $\frac{1}{4}$ sec. 28. It is operated by a company of which the members are J. F. Lester, J. D. Kipe, E. E. Pearl, and William Gordon. These two mines supply a small amount of coal to near-by

ranches and to the settlements in the vicinity of Judith Gap. There is an abandoned mine on Buffalo Creek, owned by J. A. Dover.

ROCK CREEK DISTRICT.

General conditions.—The Rock Creek district is located in T. 13 N., R. 17 E. The coal outcrop on the north side of Rock Creek in its east-west course through secs. 15 and 16 marks the southern limit of the district. Thinning of the coal limits the district in other directions, and the area of workable coal includes less than 3 square miles.

There is apparently but one coal bed in this district. It occurs in two benches, separated by a parting of dark bone. In some places the coal is overlain by bone; in others sandstone rests upon the upper bench. A representative section of the coal bed in this district is given below.

Representative section of coal bed in Rock Creek district.

		Ft.	in.
Sandstone.			
Bone.....			10
Coal.....		1	
Bone.....		1	1
Coal.....		2	2
		5	1

Carboniferous coal.—The only locality in the Lewistown field where coal was noted below the Cretaceous is in the vicinity of Rock Creek. Here a prospect in the NW. $\frac{1}{4}$ sec. 23 has discovered a 6-inch bed in the Quadrant formation, of Pennsylvanian (?) age. It is improbable that workable coal will be found at this horizon anywhere in the field, although its presence has led to some prospecting in the district between the Big Snowy Mountains and the mines on Rock Creek.

Development.—There are four mines in the Rock Creek district. Three of these—the Sharp, Cooper, and Rand mines—are along Rock Creek, and the fourth, the Knox mine, is on the west fork of Beaver Creek in sec. 3. All are small producers, supplying fuel to ranchers near by and also to the town of Moore.

WARM SPRING CREEK DISTRICT.

General conditions.—The Warm Spring Creek district comprises the northern part of T. 16 N. and the southern part of T. 17 N., R. 19 E. In a measure the limits of the district are ill defined, except where the coal outcrops in the embayment on the north-western side of the Judith Mountains. To the north the district extends across Warm Spring Creek, but the coal thins in that direction, as shown by exposures in several small laccolithic uplifts north of the creek. To the northwest the coal-bearing rocks are overlain

by the entire thickness of the Colorado shale; hence no information could be obtained concerning the thickness of the coal bed. Workable coal is found only in a very narrow strip to the north of the outcrop along the base of the Judith Mountains and a small area on the south side of Warm Spring Creek.

In the southern part of the Warm Spring Creek district there appears to be but one bed of coal, which splits to the north into three members, that number having been observed in exposures near Deer Creek. The coal bed varies greatly in character and thickness in the district, so that no representative section can be given. It is usually about 30 inches thick and is underlain and overlain by clay. Near Warm Spring Creek the coal bed thickens locally to 43 inches and occurs in two benches with a 4-inch bone parting between.

Development.—The Mace mine, in the NW. $\frac{1}{4}$ sec. 32, T. 17 N., R. 19 E., is the chief producer of the Warm Spring Creek district. The greater part of the coal obtained in this mine is taken by wagon to Kendall, a town outside of the territory mapped, in the gold-mining district of the North Moccasin Mountains. The Nevin mine, in the SE. $\frac{1}{4}$ sec. 7, T. 16 N., R. 19 E., yields a small tonnage. An abandoned mine, owned by the New Year Mining Company and formerly furnishing that company with fuel, is located near the New Year mill, in sec. 10 of the same township. The workings of this mine are being kept in repair, in view of possible resumption of metal mining in the district. There is an abandoned mine about half a mile east of the Mace mine, and another, known as the Fergus mine, is located near the center of sec. 20, T. 17 N., R. 19 E.

M'DONALD CREEK DISTRICT.

General conditions.—The largest district in the Lewistown field containing workable coal is that to the south of the Judith Mountains, the greater part of it lying near the headwaters of McDonald Creek. The northern limit of the district is defined by the coal outcrop along the base of the Judith Mountains. The outcrop along South Fork of McDonald Creek marks the southern boundary east of the McDonald Creek divide. West of this divide the coal does not extend south of the Lewistown-Forest Grove wagon road, and along the outcrop between the divide and the mines above Lewistown workable coal does not appear to be present. The producing area along Big Spring Creek affords no data regarding the extent of workable coal in any direction except to the south and southeast, so that it can not be stated definitely that this area is in reality a part of the McDonald Creek district. In the present paper, however, it is so treated.

The eastern limit of the McDonald Creek district also is indefinite. East of Forest Grove the coal outcropping along McDonald Creek indi-

cates that the Kootenai may possibly be coal bearing beyond the territory represented on the map, and the extent of the coal bed north from the outcrop can only be conjectured. In the vicinity of Giltedge, however, the coal thins; hence the district is fairly well defined in that direction. From present evidence it would seem that the McDonald Creek district includes about 75 square miles, although the coal either has been removed by erosion or is too deep for working in a considerable part of that area.

In the McDonald Creek district, as elsewhere in the Lewistown coal field, there is but one workable bed, which occurs, also as in other parts of the field, in close association with and immediately underlying the massive gray or pinkish sandstone in the lower part of the Kootenai. Below this workable bed, at a distance ranging from 15 to 40 feet, occurs another coal bed, which, because of its characteristic alternation of coal and bone in thin layers, is locally termed the "dirty vein." Above the main bed there are several coaly layers, at least in the eastern portion of the district, where seams a few inches thick were noted in the sandstone overlying the workable coal. In the vicinity of Giltedge a bed just beneath the second sandstone of the Kootenai has been prospected in several localities, but nowhere has coal more than a few inches thick been discovered. This bed is about 90 feet above the main coal bed.

Though much of the McDonald Creek district is underlain by workable coal, the thickness of the bed varies to such a degree that no representative section can be given. In all the mines but two, the Peiper and the Black Diamond, where there is only one bed without parting, the coal is in two distinct benches. For the purpose of comparison, sections from a number of localities in the area are given below.

Sections of coal beds in McDonald Creek district.

SPRING CREEK MINE.		BREW & PARSON'S MINE.	
	Ft. in.		Ft. in.
Shale, gritty.		Bone.....	5
Coal.....	2 2	Coal.....	3 2
Bone.....	6	Shale.....	2 2
Coal.....	10	Coal.....	2 6
Coal, bony.....	1 4	Clay.....	8 3
Clay.....	4 10		
BLACK DIAMOND MINE.		HILL'S MINE.	
	Ft. in.		Ft. in.
Bone.....		Sandstone.....	
Coal.....	4 4	Coal, impure.....	1 2
Clay.....		Clay.....	$\frac{3}{4}$
		Coal.....	2 4
			3 6 $\frac{1}{2}$

Development.—Development in the McDonald Creek district has been both tardy and desultory. Coal was mined on Big Spring Creek

above Lewistown and on McDonald Creek in the early eighties, but as the demand was purely local, mining operations were not extensive, and this limited demand remained without material increase until the completion of the Montana Railroad into Lewistown in the spring of 1904. Since then this railroad has obtained its steam coal from the Spring Creek mine, and is now using about 125 tons per day. Practically all the coal mined by the Spring Creek Company is loaded direct on cars at the mine for the use of the railroad, the small remainder being sold chiefly in Lewistown. The greater amount of fuel supply for that town comes from Brew & Parson's mine at the base of the Judith Mountains, or from a number of small mines—the Sharp, Flaherty, Cox, Hamilton, and Black Diamond—near the head of McDonald Creek.

An opening known as the Harmon mine is located about three-fourths of a mile southeast of the Spring Creek Company's property. Formerly this supplied a small amount of coal, but of late years it has been practically abandoned. At the time the investigation was made, however, the mine was under lease and renewal of mining operations was expected.

Other mines near Giltedge supply that vicinity. These are the Sherman, Shearson, Cliffe, and Company mines, the latter so called because it is owned and operated by the Gold Reef Mining and Milling Company. Three other mines, the Hill, Peiper, and Hobson, are located on McDonald Creek or its branches near the southern limits of the field. All the mines in the McDonald Creek district, except those operated by the Spring Creek and Gold Reef companies, are worked but little during the summer months.

The mines of the McDonald Creek district have been the chief factor in the coal production of Fergus County. The following table shows the amount of coal produced in this county for the period from 1889 to 1906, inclusive:

Coal production of Fergus County, Mont., from 1889 to 1906, inclusive.^a

Year.	Short tons.	Year.	Short tons.
1889.....	460	1898.....	950
1890.....	1,260	1899.....	900
1891.....	250	1900.....	500
1892.....	400	1901.....	5,200
1893.....	200	1902.....	9,374
1894.....	325	1903.....	19,109
1895.....		1904.....	15,228
1896.....		1905.....	29,182
1897.....		1906.....	

^a Mineral Resources U. S., 1889-1906, U. S. Geol. Survey. Statistics prior to 1889 not obtainable.

Fergus County ranks fourth in the coal-producing counties of the State, and the average price per ton in that county is considerably

greater than that received in others. This higher price is due partly to the fact that coal is not readily obtained from other fields, but chiefly because local conditions are not conducive to cheap mining.

CHARACTER OF THE COAL.

PHYSICAL CHARACTER.

The coal of the Lewistown field has certain physical characteristics which differentiate it in a measure from other coals of the State, with the exception of that from the Great Falls field, to the west. The coal is persistently banded in appearance, with alternating layers of bright and dull luster, the latter predominating. In general, therefore, the coal is dull or grayish black in color. The bright bands are thin, ranging from a mere film to one-fourth inch in thickness. The dull bands owe their appearance chiefly to the presence of mineral charcoal. Even in these bands, which at first sight appear to be entirely lusterless, closer examination shows that very minute lenses of bright coal are present. Sulphur in the form of iron pyrites (FeS_2) is more or less abundant, occurring usually in the form of small nodules or lenses, although it is present also as a thin incrustation between layers or along joint planes.

The coal in the Spring Creek and neighboring mines has near the bottom of the bed several thin partings which at first glance appear to be similar to the bright bands previously mentioned. This material will not burn readily, however, and is thrown aside as waste. It is termed "black jack" by the miners. A sample obtained at the Spring Creek mine and analyzed at the laboratory of the fuel-testing plant at Pittsburg carried 31.84 per cent of ash. In several localities, notably in the Mace mine on Warm Spring Creek, a dull, lusterless variety of coal, resembling cannel, was noted. It occurs in the Mace mine as lenses of considerable extent in the bed, the largest being 200 feet in length.

CHEMICAL CHARACTER.

Chemical analyses of the coal show that it is to be classed as medium-grade bituminous. That there is a considerable range in quality is indicated by the heat-value determinations. A sample of coal was obtained from each working mine in the field by cutting a channel across the bed from roof to floor, exclusive of partings discarded in mining.

The results of the analyses, given in the following table, are in two sets, one showing analyses of the samples as received in the laboratory and the other on an air-dried basis. The latter more nearly represent the coal as it is used commercially.

Analyses of coal samples from Lewistown field, Montana.

[F. M. Stanton, chemist in charge.]

Coal district.....		Sage Creek.	Buffalo Creek.			Rock Creek.		
Laboratory No.....		5290	5265	5267	5266	5264	5273	5274
Sample as received:								
Prox.	Moisture.....	9.95	14.44	17.03	15.72	16.86	13.90	9.18
	Volatile matter.....	24.87	28.80	27.34	29.64	30.23	26.25	29.69
	Fixed carbon.....	44.22	45.65	43.83	43.81	45.60	41.84	43.31
	Ash.....	20.96	11.11	11.80	10.83	7.31	18.01	17.82
Ult.	Sulphur.....	5.51	4.08	4.14	2.81	3.03	6.05	9.39
	Hydrogen.....			4.98		5.62		
	Carbon.....			51.73		58.27		
	Nitrogen.....			.62		.67		
	Oxygen.....			26.73		25.10		
	Calories.....	4,937		4,941		5,726	5,381	5,371
	British thermal units.....	8,887		8,984		10,307	9,686	9,668
Loss of moisture on air drying.....		3.00	7.30	9.00	6.50	8.20	6.10	1.90
Air-dried sample:								
Prox.	Moisture.....	7.16	7.70	8.82	9.86	9.43	8.31	7.42
	Volatile matter.....	25.64	31.07	30.04	31.70	32.93	27.95	30.27
	Fixed carbon.....	45.59	49.25	48.17	46.86	49.68	44.56	44.15
	Ash.....	21.61	11.98	12.97	11.58	7.96	19.18	18.16
Ult.	Sulphur.....	5.68	4.40	4.55	3.01	3.30	6.43	9.57
	Hydrogen.....			4.37		5.13		
	Carbon.....			56.85		63.48		
	Nitrogen.....			.68		.73		
	Oxygen.....			20.58		19.40		
	Calories.....	5,090		5,430		6,237	5,730	5,475
	British thermal units.....	9,162		9,774		11,228	10,315	9,855

Coal district.....		Warm Spring Creek.		McDonald Creek.				
Laboratory No.....		5472	5475	5272	5289	5295	5294	5292
Sample as received:								
Prox.	Moisture.....	2.84	6.89	15.35	18.88	11.35	18.56	14.13
	Volatile matter.....	27.35	28.61	28.27	25.18	29.74	24.59	27.37
	Fixed carbon.....	54.29	42.65	48.08	48.34	46.56	48.36	48.43
	Ash.....	15.52	21.85	8.30	7.60	12.35	8.49	10.07
Ult.	Sulphur.....	4.87	5.48	4.53	2.72	4.48	3.72	3.69
	Hydrogen.....			5.42	5.19	5.02		5.06
	Carbon.....			61.15	57.31	58.91		59.87
	Nitrogen.....			.71	.66	.82		.74
	Oxygen.....			19.89	26.52	18.42		20.57
	Calories.....	6,512	5,229	5,897	5,417	5,841	5,505	5,794
	British thermal units.....	11,722	9,412	10,615	9,751	10,514	9,909	10,429
Loss of moisture on air drying.....		1.60	2.80	8.20	6.40	3.10	9.60	7.00
Air-dried sample:								
Prox.	Moisture.....	1.26	4.21	7.79	13.33	8.51	9.91	7.67
	Volatile matter.....	27.80	29.43	30.80	26.90	30.69	27.20	29.43
	Fixed carbon.....	55.17	43.88	52.37	51.65	48.05	53.50	52.07
	Ash.....	15.77	22.48	9.04	8.12	12.75	9.39	10.83
Ult.	Sulphur.....	4.95	5.64	4.94	2.91	4.62	4.12	3.97
	Hydrogen.....			4.91	4.79	4.83		4.60
	Carbon.....			66.61	61.23	60.79		64.38
	Nitrogen.....			.77	.70	.85		.79
	Oxygen.....			13.73	22.25	16.16		15.43
	Calories.....	6,618	5,379	6,424	5,787	6,028	6,090	6,230
	British thermal units.....	11,912	9,683	11,563	10,417	10,850	10,961	11,214

Analyses of coal samples from Lewistown field, Montana—Continued.

Coal district.....		McDonald Creek.							
Laboratory No.....		5295	5293	5291	5343	5471	5473	5475	5476
Sample as received:									
Prox.	Moisture.....	12.66	12.31	12.59	9.84	8.34	15.65	7.39	7.98
	Volatile matter.....	29.62	28.41	26.71	28.70	29.87	27.05	26.31	26.63
	Fixed carbon.....	48.81	51.31	43.46	42.14	53.63	49.67	55.46	56.05
	Ash.....	8.91	7.97	17.24	19.32	8.16	7.63	10.84	9.34
Ult.	Sulphur.....	3.68	3.88	3.51	4.63	4.13	1.82	2.58	4.39
	Hydrogen.....			4.84		5.10	5.13		4.86
	Carbon.....			54.83		66.23	56.70		64.85
	Nitrogen.....			.76		.76	.70		.76
	Oxygen.....			18.82		15.62	28.02		15.80
	Calories.....	6,061	6,194	5,220	5,283	6,540	5,303	6,035	6,394
	British thermal units.....	10,910	11,149	9,396	9,509	11,772	9,545	10,863	11,509
Loss of moisture on air drying.....		6.00	6.40	5.30	3.50	3.70	9.70	2.80	3.40
Air-dried sample:									
Prox.	Moisture.....	7.09	6.31	7.70	6.57	4.82	6.59	4.72	4.74
	Volatile matter.....	31.51	30.35	28.20	29.74	31.02	29.95	27.07	27.57
	Fixed carbon.....	51.92	54.82	45.89	43.67	55.69	55.01	57.06	58.02
	Ash.....	9.48	8.52	18.21	20.02	8.47	8.45	11.15	9.67
Ult.	Sulphur.....	3.91	4.15	3.70	4.80	4.29	2.02	2.65	4.54
	Hydrogen.....			4.49		4.87	4.48		4.64
	Carbon.....			57.90		68.78	62.79		67.13
	Nitrogen.....			.80		.79	.78		.79
	Oxygen.....			14.90		12.80	21.48		13.23
	Calories.....	6,447	6,617	5,512	5,475	6,791	5,873	6,209	6,619
	British thermal units.....	11,606	11,911	9,922	9,854	12,224	10,570	11,176	11,914

Comparison of the foregoing analyses shows that there is a considerable variation in the samples, especially in moisture and ash content, the range of the former being from 2.84 to 18.88 per cent, and of the latter from 7.31 to 21.85 per cent. Sulphur is relatively high, the average being 4.25 per cent.

CONDITIONS OF MINING AND TRANSPORTATION.

The Spring Creek mine is the only one in the Lewistown field which has direct railroad connections, a spur having been extended from Lewistown up Big Spring Creek to the workings. The coal from other mines in the field is hauled by wagon, the greatest distance probably being from the McDonald Creek mines to Lewistown, about 12 miles. Not more than one or two men are employed in any of the mines except in that on Big Spring Creek, where about 40 are engaged, and this mine is the only one to use power. A steam and air-compressor plant are operated to pump water from the workings, and air drills are used in the entries. Only one other mine, the Brew & Parson, needs more than natural drainage, and in that mine excess water is removed by siphon. There is no trouble with gas in the field and no fans are in operation.

Practically all the mines in the district are opened directly on the dip, which is nowhere excessive, and cars are hauled from the entries by mule or more commonly pushed by hand. The abandoned New Year mine and the Nevin mine, in Warm Spring Creek basin, are opened on the strike, the coal bed dipping at a rather high angle.

The problem of timbering is in general not difficult of solution, as the roof is usually compact shale or sandstone. In a number of the small mines no timbering is needed. Timber is obtained from the various mountain uplifts bordering or within the field, or from the vicinity of the McDonald Creek divide and Rock Creek.

FUTURE DEVELOPMENT.

The Lewistown coal field has been and seems destined to remain a region independent of other coal fields, and yet is so situated geographically that it can not well compete with other coal-producing sections of the State in their respective markets. East and north of the field there are extensive areas which seem unlikely to remain other than sparsely settled. To the south lies the Bull Mountain coal field, which is receiving an impetus in development from the construction of the transcontinental line of the Chicago, Milwaukee and St. Paul Railway. This line passes directly through the Bull Mountain field, and will furnish an outlet for the coal. The towns along the Northern Pacific in south-central Montana procure their coal from the Red Lodge, Bear Creek, Bridger, and other coal districts in the vicinity of the railroad. To the northwest is the Great Falls coal field, which controls the market in that section of the State. The Billings and Northern Railroad, which connects Billings and Great Falls, passes through Judith Gap and across the western portion of the Lewistown coal field. Although this line will do much to hasten development in the Great Falls field, especially in the Otter Creek and Sage Creek districts, it has at present no direct connection with the coals of the Lewistown field. Even if a branch line is built to Lewistown, the coals of that district can scarcely compete with those of the Sage Creek district, where they can be mined more economically principally because of greater thickness of the bed.

It seems, then, that the Lewistown coal field must continue to supply a local market only. In spite of this probability, however, there is likely to be a constant increase in the demand for the coal. The region is one well adapted to agriculture, and of late years there has been a notable increase of population. Lewistown is a thriving business center, and other towns within the field are growing rapidly. With the disappearance of the forests in the near-by mountains, an almost accomplished fact in the Little Belt, Judith, and Moccasin uplifts, and with an increasing demand for fuel from the growing population and the metal-mining districts, it seems likely that there will be a corresponding increase in the use of coal in the Lewistown

THE SHERIDAN COAL FIELD, WYOMING.

By JOSEPH A. TAFF.

INTRODUCTION.

This report is a brief discussion of the economic geology of the coal in the Sheridan field, Wyoming, and includes in addition only so much of the stratigraphy, topography, structure, and culture as seem to have a bearing on the development of the coal field. A more complete report on the coal fields of northeastern Wyoming, east of the Bighorn Mountains, is contemplated, to be prepared when geologic surveys are carried farther south and east.

The Sheridan field is covered by public-land surveys, and no maps other than township plats were available for field use, with the exception that a small part of the coal area west of the longitude of Sheridan is within the Dayton quadrangle and has been surveyed topographically. The principal object in the survey being the classification of the coal land, it was necessary that all points should be located with reference to the Land Office unit of subdivision—the section. Many of the section corners could not be found, even in the larger valleys where settlements have been made. In the rougher parts of the field the number of corners that could be found was still less, and many of those that were located contained no distinctive markings. Local county and other surveyors report that great difficulty has been encountered in locating settlers upon their lands, the only corners that could be found being in many cases several miles distant from these lands. Moreover, the locations of stream crossings on section lines and of other topographic features shown on the township plats were found to be so erroneous as to suggest that a considerable part of the land subdivisions had never been made.

The map (Pl. VIII) accompanying this paper is based on compass surveys tied to known land corners and to each other. Distances were measured by pacing on section lines or from section corners. In the eastern and central parts of the field but few section corners could be found. The traverse lines between known section corners were long, and even when these lines are adjusted to each other and to the known corners the locations of many points are only approximately correct.

The writer was assisted in the field work by Albert W. Thompson and Fred H. Kay, and in the office by Mr. Kay. The larger part of the results obtained in the season's work is due to the competent services of these men. The officers of the coal-mining companies located at Dietz, Carneyville, Monarch, and Kooi, together with individual owners of coal lands, rendered valuable assistance.

LOCATION AND GEOGRAPHIC RELATIONS.

The Sheridan coal field is located in northeastern Wyoming, to the east of and near the Bighorn Mountains. The northern edge of the field is the Wyoming-Montana State line, and is arbitrarily chosen

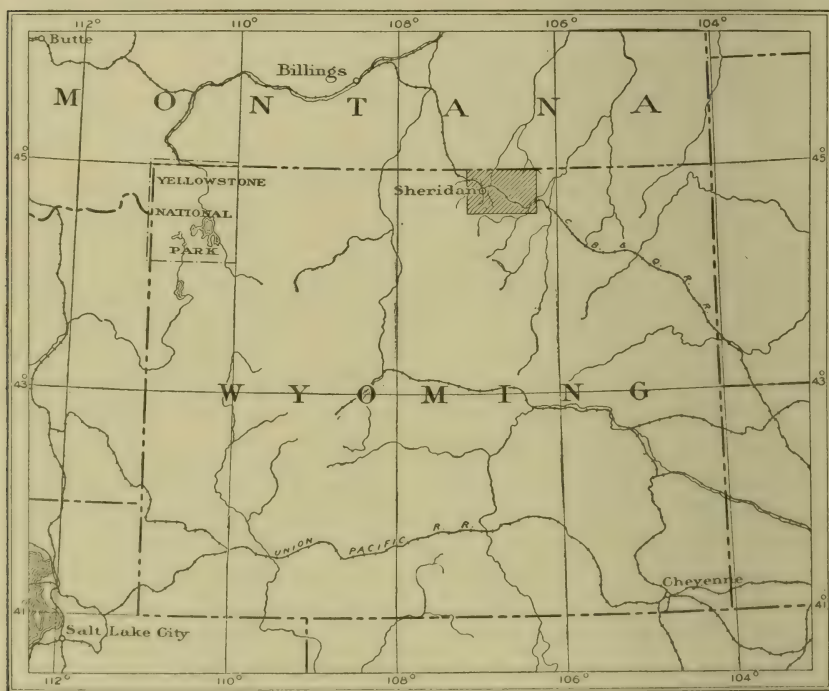
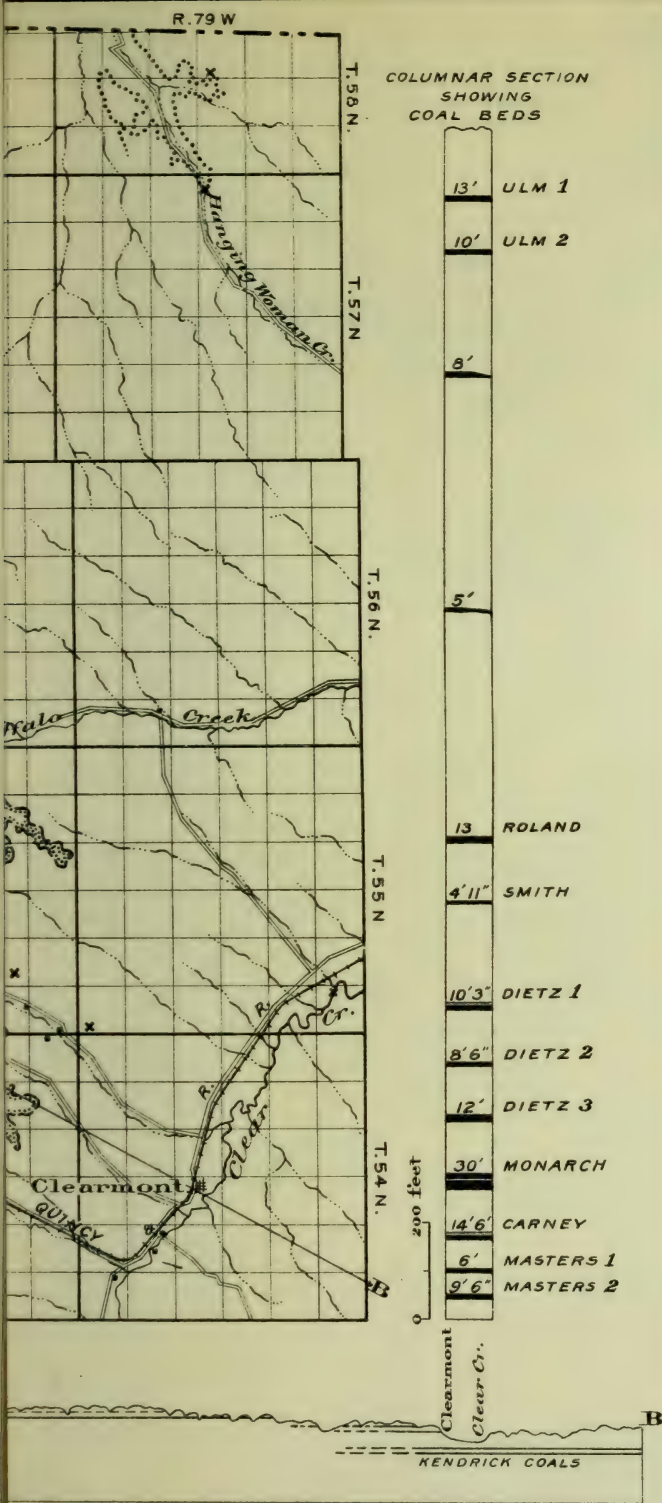
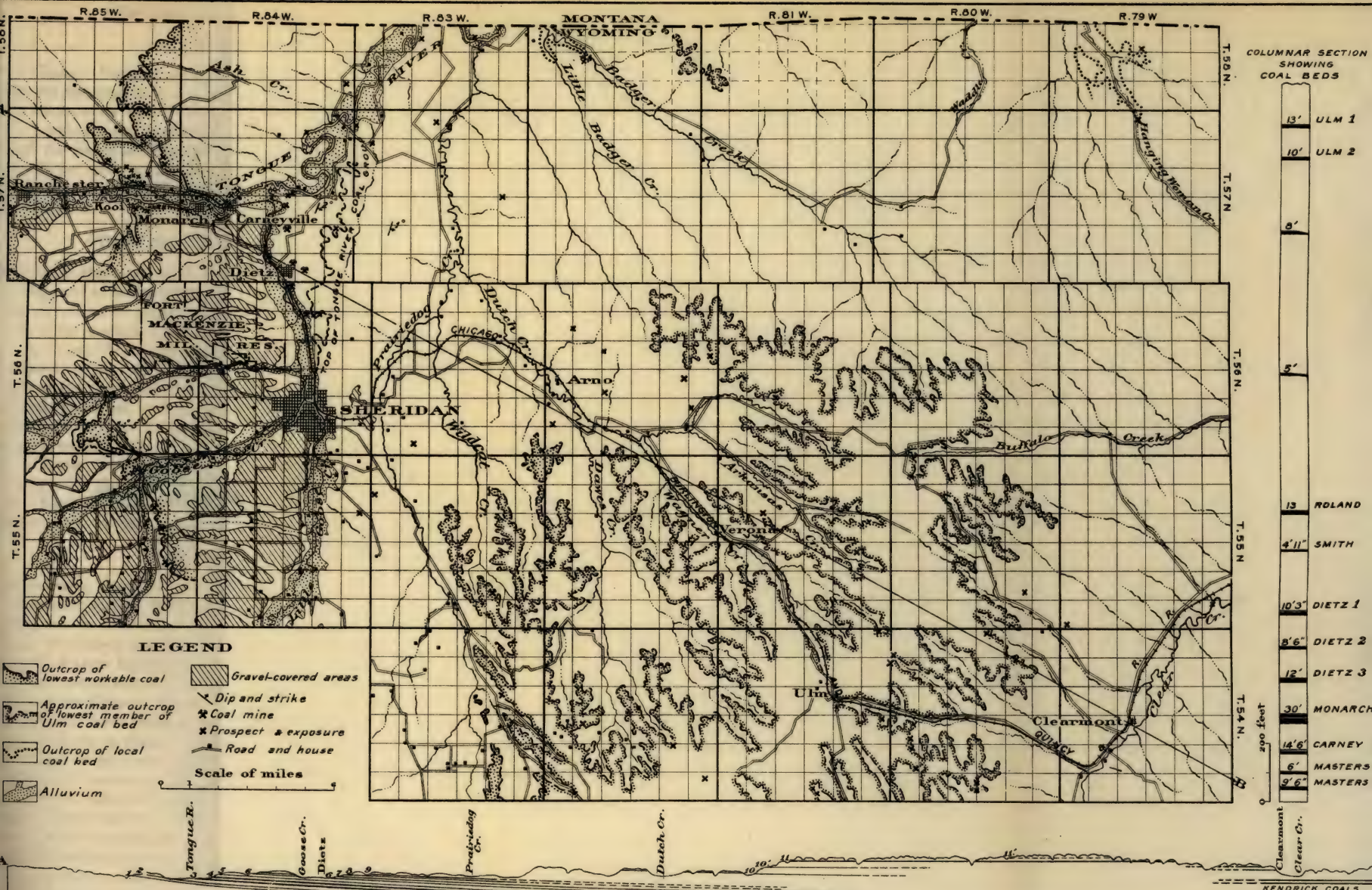


FIG. 3.—Index map showing location of Sheridan coal field, Wyoming.

without reference to the boundary of coal-bearing rocks. Likewise the eastern and southern borders are conveniently situated on range and township lines and have no particular geologic significance, being chosen to mark the limits of the surveys of the season. The western boundary of the coal field, however, is the western boundary of the rocks that contain workable coal beds. The field thus defined is a part of the Fort Union coal region, which extends from northeastern Wyoming into eastern Montana and North Dakota. The Wyoming part of this larger region is in the wide, flat trough or basin between the Black Hills and the Bighorn Mountains.





1= Lower Masters. 2= Upper Masters. 3= Carney. 4= Monarch. 5= Dietz 3. 6= Dietz 2. 7= Dietz 1. 8= Smith. 9= Roland. 10 and 10'= Local coals. 11 and 11'= Ulm coals.

ACCESSIBILITY.

The Chicago, Burlington and Quincy Railroad, a single-track line, crosses the Sheridan field in a general northwest-southeast direction. It has connections with trunk-line roads in Nebraska and Montana to the southeast and northwest. Railroad construction is feasible through the Sheridan field northward along either Powder River or Tongue River valley to the Northern Pacific Railway on Yellowstone River in Montana, and from the Burlington Railroad southward up Powder River.

CULTURE AND WATER SUPPLY.

Sheridan is the commercial center of the coal fields of northeastern Wyoming, and is the largest town in the northern part of the State, having an estimated population of 8,000. Dietz, on Goose Creek 2½ miles from its junction with Tongue River, and Carneyville and Monarch, on Tongue River, are the three principal mining towns. They have about 2,000, 1,400, and 700 inhabitants, respectively, and the energies of the people are devoted solely to coal mining, about 1,600 men being employed in the operations. Within a year Kooi and Riverside, farther up Tongue River, have been established for coal-mining purposes.

Clear, Little Goose, and Goose creeks and Tongue River, having their sources in the Bighorn Mountains, afford a supply of excellent water. Their alluvial bottom lands, aided by abundant water for irrigation, support thriving farming communities.

TOPOGRAPHY.

The Sheridan coal field is in the western edge of the broad plain that extends from the Bighorn Mountains to the Black Hills. The plains feature in this field is referable, however, only to the crests of the main watersheds and higher ridges between the principal valleys. The crests of these highlands undulate between levels of nearly 4,200 feet in the eastern end of the field to 4,600 feet at the approach to the foothills of the Bighorn Mountains. Here and there the headwaters of the streams have reduced the highlands to zigzag sharp-crested ridges, which are in places intersected by shallow gaps.

The larger valleys are graded and the streams meander in flat, alluvium-filled bottoms. The lowest point in the mapped area is in Tongue River valley at the State line, and is nearly 3,400 feet above the sea. Thick coal beds have been burned in many places near the outcrop, producing extensive clinker beds and metamorphosing the strata that overlie the coal. These clinkers and baked strata are very resistant, and, as a consequence, are now found capping steep terraces, spurs, buttes, and cones.

Broad stretches of flat, gravel-covered benches and gently sloping table-lands make a large part of the country contiguous to the valley of Little Goose Creek, and between Little Goose Creek and Tongue River.

The valleys of Goose and Little Goose creeks and Tongue River are floored with a thick deposit of gravel, sand, and silt, and are wide and flat.

DRAINAGE.

Tongue River and Little Goose, Goose, and Clear creeks are the only streams within the mapped area that have a continuous flow. These streams afford an abundant supply of excellent water. Their sources are toward the crests of the Bighorn Mountains, where snow lies during a large part of the year and where rainfall is more abundant than in the plains country surrounding the mountains. All the other valleys have intermittent streams that are dependent on the scanty rainfall of the plains region.

FOREST CONDITIONS AND TIMBER SUPPLY.

The Sheridan district has no forests. The few trees in the valleys consist of cottonwood, ash, etc., that are found in scattering growths near the streams. Pine and cedar grow here and there on the more stony uplands. More rarely scrub oaks are found in protected gulches near the heads of the valleys. The Bighorn National Forest, a few miles west of the mapped area, will afford ample timber supply for all needs of mining. Timber for mines, railroads, and other purposes is floated down Tongue River to the railroad near Ranchester.

GEOLOGY.

STRATIGRAPHY.

GENERAL OUTLINE.

It is proposed to discuss here only the rock formations that contain the coal, together with the formation that lies in contact below and the surficial gravels and alluvium above, that have, or seem to have, economic bearing on the development of the coal resources. The surficial deposits are the only formations in this district that overlie the coal-bearing rocks. The formations that lie below the coal-bearing strata require further field study for better age classification. Two or more of these lower formations crop out across the southwestern part of T. 55 N., R. 85 W. All the remaining part of the Sheridan field as mapped contains coal-bearing strata, except in the areas of surface gravel and alluvium. The geology of the coal-bearing rocks has been briefly discussed by Darton.^a

^a Darton, N. H., *Geology of the Bighorn Mountains*: Prof. Paper U. S. Geol. Survey No. 51, 1906; also *Bald Mountain-Dayton folio* (No. 141), *Geologic Atlas U. S.*, U. S. Geol. Survey, 1906.

The formation that immediately underlies the coal-bearing rocks consists of a group of thick beds of drab to brown sandstone that are separated by blue clay and brownish or black carbonaceous shale layers. The carbonaceous shale contains a few thin seams of coal, but no coal of any commercial value is known to occur in the formation. This has been named the Piney formation in the Bald Mountain-Dayton folio. Southward from Tongue River the outcrops become gradually obscure, until but little can be seen of them on Goose Creek near the southwest corner of the area mapped. The obscure exposures are evidently due to the gravel that has been spread over much of the upland.

This formation has been correlated ^a locally with the Fox Hills sandstone, of known Cretaceous age, and referred to as a definite marker below the coal. Its exact age is not yet known, and it is too far beneath the coal beds to be of any economic value as a datum for reference.

COAL-BEARING ROCKS.

The rocks that contain the coal in the Sheridan field consist of comparatively soft shale and sandstone, alternately stratified and in apparently conformable succession. The shales vary widely in composition from clay through carbonaceous clay to coaly shale or bone, on the one hand, and from clay to sandy clay and shaly sand on the other. The more clayey shale is, as a rule, very slightly, if at all, indurated, except where the burning of coal beds has changed its texture. The sandstone and shaly sandstone strata are generally friable or consist of only partially consolidated sand that breaks down readily into loose sand on exposure. Here and there in the section, however, there are certain sandstone beds that have been changed to stony hardness, and weather out in projecting ledges. Such indurated beds are more or less local, and no individual sandstone formation is traceable by its exposures for a great distance.

The coal-bearing rocks are divisible into two parts, which may be called the lower and upper members, distinguished by the relative quantities of sandstone and shale and by the general color of the rocks. The dividing line is near the middle of the rock section as exposed in the Sheridan field and is marked approximately by the Carney coal bed, as it is known on Tongue River.

LOWER MEMBER.

The rocks below the Carney coal are essentially all shale or are shaly in character and prevailingly dull drab, bluish, and brown in color. They contain numerous segregations of ferruginous, globular concretions, many of which are several feet in diameter. On weathering

^a Kennedy, Stewart, The lignites of northeastern Wyoming: Mines and Minerals, vol. 27, 1907, pp. 294-297.

they take on yellow to brown rusty hues and break into angular lumps of small size. These segregations of ferruginous, sandy clay are more abundant in the upper part than elsewhere in the member. Bluish shale of varied texture, interspersed with a great number of beds of carbonaceous shale, makes up the greater part of the rock section. The carbonaceous strata range from thin seams to beds 15 to 20 feet thick, and locally contain thin bands of coal. At one locality near the State line, west of the mapped area, 800 to 1,000 feet below the top of the member, there is a variable and local bed of coal separated into benches by several bands of blue clay and brown carbonaceous shale. The coal layers aggregate 5 feet in thickness at one place. At another place near by the total thickness of coal is 4 feet 10 inches. Near the top of the member, as exposed on the north side of the Tongue River valley, there are two other coal beds that appear to be of local extent. One is nearly 60 feet above the other, and they are separated by dark shale. The upper of the two beds is about 75 feet below the Carney coal bed, from which it is separated by bluish shale and thin beds of brown sandstone. These two coal beds are each about 6 feet thick on the north side of the Tongue River valley, in T. 57 N., R. 85 W., and are locally known as the Masters coal beds.

The total thickness of the lower member north of Tongue River is estimated to be 2,500 to 2,800 feet. The exposures are so obscure south of Tongue River that reliable estimates of the thickness there could not be made.

UPPER MEMBER.

General character.—The rocks from the lower member upward to the top of the section exposed in the Sheridan district consist of shale, sandstone, and coal, in many beds interstratified. It is estimated that the aggregate thickness of the shale is approximately twice that of the sandstone. The shales range from clay of bluish tints to brown carbonaceous clay and bony coal, on the one hand, and from clay through grades of sandy clay to shaly sandstone, on the other. In weathered surfaces the shale and sandstone, aside from the carbonaceous beds, present various hues of light yellow, brown, and white, except where the burning of the coal has transformed them to hues of red and pink. The sandstones range in color from drab or brown to white. The carbonaceous strata, being originally black to dark brown, retain a dark shade until weathered to soil. As a whole the surface coloring is yellow.

The thickness of the upper member exposed in the Sheridan district is estimated to be not less than 2,200 feet. The rocks are very slightly tilted or lie in a horizontal position, and the edges of the beds are spread over a wide area. As elevations were obtained by means

of aneroid barometers, the determinations of thickness of strata are only approximately correct.

With respect to the occurrence of coal, this member may be separated into three divisions. From the base upward, through nearly 800 feet of rock, there are at least seven workable beds of coal. These coal beds are exposed principally in the valley of Tongue River, and for convenience of reference and economic discussion they will be termed the Tongue River coal group.

Tongue River coal group.—The lowest workable bed of this group is known as the Carney bed. It occurs in two benches in the Tongue River Valley. The upper bench is 4 feet 6 inches thick, and the lower between 10 and 11 feet. The two benches are separated by a thin parting of shale.

The next workable bed occurs about 86 feet higher in the section on Tongue River, and is known locally as the Monarch bed. This bed also is divided into two benches. The upper one is reported to be nearly 10 feet thick and to contain partings of shale. The lower bench is 18 to 22 feet thick, as reported from drill prospecting and mine working. Part of the coal is left for roof in mining until the pillars are robbed, therefore a full section of the coal could not be seen. A large part of the rock between the Carney and Monarch coal beds consists of white, massive sandstone. In the bluffs of Tongue River at Carneyville the sandstone is nearly 60 feet thick. A variable thin shale lies between it and the Carney coal, and a thicker bed of shale separates it from the Monarch bed above.

Nearly 120 feet above the Monarch coal bed there is another bed, known as the Dietz No. 3 coal. This is not exposed directly above a known outcrop of the Monarch bed, its identity being determined from records of drilling and structural conditions between Monarch and the junction of Goose Creek and Tongue River. A prospect near the mouth of Goose Creek exposes 6 feet of the Dietz No. 3 bed, and it is reported to be 12 to 14 feet thick in prospect drillings. The rocks between the Monarch and Dietz No. 3 coals consist of bluish shale and thin-bedded and shaly drab sandstone.

Another coal bed, known as the Dietz No. 2, lies about 100 feet above the Dietz No. 3. Its known thickness is 8 to 9 feet, and it is reported to thicken locally to 14 feet. Dietz coal bed No. 1, the fifth in the Tongue River coal group, counting from the base, occurs 100 to 115 feet above Dietz bed No. 2. This bed is $8\frac{1}{2}$ feet thick near Dietz, and is succeeded by an upper bench 18 inches to 2 feet thick, with a gray shale of the same thickness intervening. The same bed is exposed in the bluffs of Tongue River near the mouth of Goose Creek. The rocks separating the Dietz coal beds consist of yellow to brown sandstone, bluish shale, and brown carbonaceous shale in beds of variable thickness. Certain thick sandstone beds between Dietz

coals Nos. 1 and 2 make bluffs along Goose Creek north of Dietz and on Tongue River east of Goose Creek.

A sixth coal bed in the Tongue River group is exposed 210 to 215 feet above Dietz bed No. 1, in the hills south of Dietz, where it is mined for local use. The coal here is nearly 5 feet thick and is referred to as the Smith coal, from the name of the operator of the local mine. A massive white sandstone 20 feet thick underlies the blue-shale floor of the coal. The outcrop of the sandstone makes a white band and is a marked feature of the hills both northeast and south of Dietz. The rocks are chiefly shale from this white sandstone down to Dietz coal No. 1.

The uppermost bed at present known of the Tongue River coal group occurs 125 feet above the Smith coal, and is separated from it by shale with a few thin sandstone beds. This coal bed has been prospected and mined for local consumption 2 miles northeast of Dietz by Mr. Roland, and may be known for purposes of description as the Roland coal. The bed at this locality is 13 feet thick. Between Dietz and Sheridan the Roland coal bed is believed to be replaced by a thick bed of bituminous shale, with bands of bony coal 2 feet and less in thickness in its midst.

Intermediate coal group.—From the Roland coal, which marks the top of the Tongue River coal group, upward 700 feet the rocks are composed chiefly of shale. Here and there are thin strata of white to brown sandstone. Bands of carbonaceous shale are of common occurrence, and there are several beds of coal that are evidently limited to small areas. Continuing upward there are 450 to 470 feet of shale and sandstone in alternating strata, each kind of rock being nearly equal to the other in aggregate thickness. A number of carbonaceous shale beds 10 to 20 feet thick were noted, with a few beds of coal of workable thickness though of small areal extent.

Ulm coal group.—Two workable beds of coal of considerable areal extent occur in the rock section 1,100 to 1,200 feet above the top of the Tongue River coal group. Over the larger part of the Sheridan field these upper coal beds have been removed by erosion. Their remnants are found in the south-central part of the mapped area, near the top of the watershed between Tongue River and Clear Creek. These two coal beds are termed for convenience the Ulm coal group, because of their best known occurrence in the vicinity of Ulm, on the Burlington Railroad. They are separated by about 100 feet of shale and soft sandstone beds similar to the sandstone and shale lying below. The Ulm coal beds vary both in section and thickness. Exposures of these beds, however, are rare on account of the extensive burning they have suffered near the surface. Both beds are broken by shale partings, usually into two or more benches, but the total coal in each is ample for mining. Above these two coal beds

there is an estimated thickness of 200 feet of soft shale and whitish to light-yellow sandstone, making the topmost part of the section of rocks exposed in this field.

VARIATIONS IN THE COAL-BEARING ROCKS.

A considerable part of the coal-bearing rocks change in character in certain respects toward the south, in the general direction of the strike of the beds. Near the State line, in T. 58 N., R. 86 W., certain light-colored sandstone strata in the upper part of the lower member thin out and disappear southward along the strike. Some brownish and yellow sandy strata that lie still higher, near the top of the same member on Tongue River, seem to thin out toward the south and give place to dull-colored shale or sandy strata on Goose and Beaver creeks in T. 55 N., R. 85 W. These conditions seem to indicate that the parting between the two members rises in the rock section toward the south.

The upper member also changes in character southward along the strike of the rocks. From the central part of the field southward the differentiation between the sandstone and shale strata becomes less distinct. The sandstone on the whole is duller in color, and near the southern boundary of the mapped area the sandstone beds contain pebbles of limestone, quartz, and chert. In the southeastern part of T. 54 N., R. 83 W., and in T. 54 N., R. 84 W., many hundred feet of strata in the central part of the upper member merge into conglomerate. The constituent parts of the conglomerate become coarser rather abruptly on the approach to the Paleozoic rocks of the Bighorn Mountains, upon which the conglomerates overlap unconformably. The exposed section of conglomerate strata is more than 1,000 feet thick between Little Goose and Sandy Creek valleys, at the base of the Bighorn Mountains, on the southern border of the Sheridan field. The gradation from the conglomerate into the sandy and shaly strata takes place toward the east and north, and involves almost the whole section of this member from the Tongue River coal group upward nearly to the top of the rock section. The economic bearing of the conglomerate is a negative one, for the coal beds thin out and disappear near its outer fringe.

AGE OF COAL-BEARING ROCKS.

Many collections of fossil plants were made at various places throughout the section of the coal-bearing rocks, and fossil shells were collected at various places in the section from the Tongue River coal group upward. Reports on the plants by F. H. Knowlton and on the shells by T. W. Stanton agree in stating that the rocks which included the fossil collections are of Fort Union age. At the present time the tendency is to class the Fort Union as lower Eocene (basal Tertiary).

STRUCTURE.

The rocks in the western part of the Sheridan field are tilted at low angles in a generally eastward direction. From the Tongue River valley southward on the strike of the lowest coal outcrop the rocks dip about 4° E. Northward from Tongue River the dip is toward the southeast at about the same angle. These dips produce a shallow eastward-pitching trough or basin. East of the mouth of Goose Creek this basin structure is scarcely perceptible. Similar structure, if it is not the same shallow trough, can be seen in the western slopes of the Badger Hills, in T. 58 N., R. 82 W., when viewed from a distance. The warping of the strata here is so slight that it is not perceived unless a considerable part of the broad fold is in view. North of the mouth of Goose Creek the northeasterly dip, though slight, is resumed. The tilt of the rocks eastward grows gradually less on the whole, but with local variations in degree. On the east side of the Goose Creek valley the dips average about 3° . In the Prairie Dog Creek valley it is only 1° . Farther east and continuing to the Powder River valley, beyond the area mapped, the rock strata are essentially horizontal.

THE COAL.

GROUPING OF COAL BEDS.

As noted previously, the coal beds of this field are divided into three groups, each group depending on the association of certain beds and their seeming continuity in lateral extent.

Order and thickness of the coal beds in the Sheridan field.

ULM COAL GROUP.

	Feet.
Upper Ulm coal bed (variable).....	12
Lower Ulm coal bed (variable).....	16

INTERMEDIATE COAL GROUP.

Several workable coal beds of local extent, probably eight in number, varying in thickness up to 9 feet; total maximum thickness about 30 feet.

TONGUE RIVER COAL GROUP.

Roland coal bed (variable).....	13
Smith coal bed (variable).....	5
Dietz coal bed No. 1.....	8
Dietz coal bed No. 2.....	8
Dietz coal bed No. 3 (variable).....	12
Monarch coal bed.....	18-32
Carney coal bed.....	12-17
Masters upper coal bed.....	6
Masters lower coal bed.....	6

Estimated average of known exposures.....	149
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The Ulm coal group occupies but a relatively small part of the Sheridan district, and the amount of coal has been further reduced by burning of the beds. Each of the coal beds of the intermediate coal group, as estimated, is of workable thickness in only a small part of the field. Some of the workable beds in the Tongue River coal group are known to thin out, and others doubtless vary in thickness from place to place. It can not be assumed, therefore, that the average thickness of coal for the whole area can be more than a small fraction of the total average of the known thickness of the separate beds.

PHYSICAL PROPERTIES OF THE COAL.

The coal beds in the Tongue River group are so nearly uniform in physical character that select specimens from one bed can scarcely be distinguished from like specimens from other beds. All these coals are distinctly black and have a shiny luster when fresh. On exposure in dry air the blackness is intensified by a partial loss of the shiny luster and the coal assumes a dull, dead blackness. At the same time it undergoes a rapid change by the loss of free moisture, which causes it to check or crack in various directions. Though weakened by shrinkage through a partial loss of water the coal will adhere together as mined for an indefinite time if protected from the weather. When it is subjected to alternate wetting and drying, however, it breaks into small lumps and finally is reduced to a powder-like dust. For these reasons the coals are marketed more successfully by shipment in box cars. The streak of fine dust produced by abrading the coal is distinctly brown. The coals in the thicker beds especially are not as a rule distinctly laminated, but are for the most part massive. In mining they break into angular or subcubical blocks that present hackly and conchoidal surfaces. The coal in this district is not regularly or distinctly jointed and in mining is undercut by pick or machine and shot from the solid.

Though the coals of the Tongue River group contain a comparatively high percentage of water and disintegrate on exposure, like the lignites, they do not show woody structure. Some of the coal beds in the upper part of the intermediate group and in the Ulm group show the texture or fiber of certain plants that took part in forming the coal. These coals are homogenous, however, and black like the coal beds lower in the section, but their water content is a little greater than that of the coals on Tongue River. Their fuel value also is a little lower, as indicated by the calorific determinations.

QUALITY OF THE COAL.

The coals that have been tested chemically are considered to be representative, with few exceptions, of the several beds that have been examined. The samples believed not to be truly representative were obtained from shallow workings and from mines near the outcrop, and are thought to have suffered a partial loss of volatile matter, due to the more or less free access of air. Such samples seem to show a higher percentage of moisture than the average coal of the same beds, though the coal at the time the samples were collected did not contain an apparent excess of water. Samples Nos. 5 and 6 in the table of analyses were taken from the same mine, one under a thick and the other under a thin covering of rock. Nos. 2 and 4 represent samples from the same bed, one in a deep mine and the other under shallow cover. It is probable, therefore, that coals represented by samples Nos. 4, 6, 7, 8, 20, 21, and 22 contained reduced components of volatile matter and a slight excess of moisture, so that the samples as received and in the air-dried state are not truly representative of the beds from which they were taken. However, they were the best that could be obtained at the time examinations were made and are approximate within a small percentage.

All the coal samples were collected in conformity, as nearly as possible, with the regulations of the fuel-testing plant. Each sample is first subjected to warm, dry air in a protected vessel until the free moisture is evaporated and the coal has attained practically a constant weight. In this state it is said to be air dried and is analyzed. The analysis is then recalculated back to the condition of the sample as received. A comparison of these two analyses indicates the approximate relative fuel values of the coal in its moist and dry state.

The chemical analyses show that the coals of the Sheridan district as a whole have higher heat values and are therefore more efficient fuels than the better grades of lignites. These coals are black and in that respect are also unlike the lignites, which are brown. Because of their general homogeneous texture, blackness, and fuel efficiencies the Sheridan coals are distinctly separate in quality from lignites. On the other hand, they are distinguished from bituminous coals chiefly on account of their relatively high percentage of moisture, conchoidal fracture, varying luster, and inability to withstand weathering agencies. The average bituminous coal contains considerably less than 10 per cent of moisture, has angular or cubical as distinguished from conchoidal fracture, retains luster, and will not check or slack on exposure to the weather. The coal of the Sheridan district stands between bituminous coal and lignite, and is to be classed as subbituminous.

The chemical analyses here given were made at the laboratory of the Geological Survey fuel-testing plant, Pittsburg, Pa.

Analyses of coal samples from Sheridan field, Wyoming.

[F. M. Stanton, chemist in charge.]

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Coal bed.....	{ Upper Mas- ters.	Carney (lower bench).	Carney (upper bench).	Carney.	Mon- arch (under thick cover).	Mon- arch (near crop).	Monarch.		Mon- arch(?)
Location.....	{ Sec. 14, T. 57 N., R. 85 W.	Carneyville.		Sec. 12, T. 57 N., R. 85 W.	Monarch.		Sec. 24, T. 57 N., R. 85 W.	2 miles west of Mon- arch.	Sec. 3, T. 55 N., R. 85 W.
Laboratory No.....	5389.	5388.	5387.	5394.	5386.	5395.	5393.	5391.	5392.
Sample as received:									
Prox. { Moisture.....	22.71	22.76	21.45	24.36	21.39	23.58	22.63	24.10	23.00
Prox. { Volatile matter.....	34.78	34.22	35.08	35.79	35.36	37.98	37.27	37.49	35.10
Prox. { Fixed carbon.....	36.60	39.58	39.08	36.90	40.03	34.87	37.21	34.60	37.15
Prox. { Ash.....	5.91	3.44	4.39	2.95	3.22	3.57	2.89	3.81	4.75
Ult. { Sulphur.....	.29	.35	.75	.32	.31	.49	.21	.34	.29
Ult. { Hydrogen.....	6.14	6.03	5.81	.....	.....	.....	.....	.....	6.14
Ult. { Carbon.....	52.54	54.89	54.89	.....	.....	.....	.....	.....	53.01
Ult. { Nitrogen.....	1.03	1.02	1.00	.....	.....	.....	.....	.....	1.06
Ult. { Oxygen.....	34.09	34.27	33.16	.....	.....	.....	.....	.....	34.65
Calories.....	5,115	5,239	5,398	5,079	5,367	5,149	5,260	5,080	5,090
British thermal units.	9,207	9,430	9,716	9,142	9,661	9,268	9,468	9,144	9,162
Loss of moisture on air drying.....	9.50	6.60	6.60	7.20	8.40	6.90	5.80	9.50	9.50
Air-dried sample:									
Prox. { Moisture.....	14.60	17.30	15.90	18.49	14.18	17.92	17.87	16.13	14.92
Prox. { Volatile matter.....	38.43	36.64	37.56	38.57	38.60	40.80	39.56	41.43	38.78
Prox. { Fixed carbon.....	40.44	42.38	41.84	39.76	43.70	37.45	39.50	38.23	41.05
Prox. { Ash.....	6.53	3.68	4.70	3.18	3.52	3.83	3.07	4.21	5.25
Ult. { Sulphur.....	.32	.38	.80	.34	.34	.53	.22	.38	.43
Ult. { Hydrogen.....	5.61	5.67	5.44	.....	.....	.....	.....	.....	5.61
Ult. { Carbon.....	58.06	58.77	58.77	.....	.....	.....	.....	.....	58.58
Ult. { Nitrogen.....	1.14	1.09	1.07	.....	.....	.....	.....	.....	1.17
Ult. { Oxygen.....	28.34	30.41	29.22	.....	.....	.....	.....	.....	28.96
Calories.....	5,652	5,699	5,779	5,473	5,859	5,531	5,584	5,613	5,624
British thermal units.	10,173	10,096	10,403	9,851	10,547	9,955	10,051	10,104	10,124
	10.	11.	12.	13.	14.	15.	16.	17.	18.
Coal bed.....	Monarch (?)		{ Dietz No. 3.	Dietz No. 2.			Dietz No. 1.		Evans.
Location.....	{ Sec. 11, T. 55 N., R. 85 W.	Beaver Creek, sec. 14, T. 55 N., R. 85 W.	Sec. 22, T. 57 N., R. 84 W.	Sec. 27, T. 57 N., R. 84 W.	Dietz.		½ mile south of Dietz.	Dietz.	Sec. 2, T. 55 N., R. 84 W.
Laboratory No.....	5747.	5390.	5383.	5384.	5378.	5385.	5379.	5381.	5377.
Sample as received:									
Prox. { Moisture.....	19.87	24.12	19.83	22.38	22.86	21.26	22.53	24.70	20.38
Prox. { Volatile matter.....	35.98	38.27	35.05	31.85	33.21	34.08	35.30	37.55	34.19
Prox. { Fixed carbon.....	38.86	29.42	38.91	39.42	37.05	37.75	34.46	33.04	42.04
Prox. { Ash.....	5.29	8.19	6.21	6.35	6.88	6.91	7.71	4.71	3.39
Ult. { Sulphur.....	.47	1.06	.94	1.16	1.22	1.12	.86	.39	.47
Ult. { Hydrogen.....	.....	.....	5.86	6.32	.....	.....	.....	6.24	.....
Ult. { Carbon.....	.....	.....	53.21	52.25	.....	.....	.....	51.50	.....
Ult. { Nitrogen.....	.....	.....	1.08	1.19	.....	.....	.....	1.07	.....
Ult. { Oxygen.....	.....	.....	32.70	32.73	.....	.....	.....	36.09	.....
Calories.....	5,089	4,692	5,148	5,137	5,001	5,124	5,021	4,946	5,435
British thermal units.	9,160	8,446	9,266	9,247	9,002	9,223	9,038	8,903	9,783
Loss of moisture on air drying.....	8.90	6.90	7.00	8.10	8.70	6.30	6.70	10.40	7.10
Air-dried sample:									
Prox. { Moisture.....	12.04	18.49	13.79	15.54	15.51	15.97	16.97	15.96	14.30
Prox. { Volatile matter.....	39.49	41.11	37.69	34.66	36.37	36.37	37.84	41.91	36.80
Prox. { Fixed carbon.....	42.66	31.60	41.84	42.89	40.58	40.29	36.93	36.87	45.25
Prox. { Ash.....	5.81	8.80	6.68	6.91	7.54	7.37	8.26	5.26	3.65
Ult. { Sulphur.....	.52	1.14	1.01	1.26	1.34	1.20	.92	.43	.51
Ult. { Hydrogen.....	.....	.....	5.46	5.90	.....	.....	.....	5.67	.....
Ult. { Carbon.....	.....	.....	57.22	56.86	.....	.....	.....	57.48	.....
Ult. { Nitrogen.....	.....	.....	1.16	1.29	.....	.....	.....	1.19	.....
Ult. { Oxygen.....	.....	.....	28.47	27.78	.....	.....	.....	29.97	.....
Calories.....	5,586	5,040	5,536	5,590	5,477	5,469	5,382	5,520	5,850
British thermal units.	10,055	9,072	9,963	10,062	9,860	9,843	9,687	9,936	10,531

Analysis of coal samples from Sheridan field, Wyoming—Continued.

	19.	20.	21.	22.	23.	24.	25.	26.
Coal bed.....	Smith.	Roland.	Badger Creek.	Ken- drick.	Powder River.			
Location.....	{ 3 miles north of Sheri- dan.	Sec. 25, T. 57 N., R. 84 W.	Sec. 29, T. 53 N., R. 82 W.	Sec. 2, T. 8 S., R. 43 E., Mon- tana.	Sec. 21, T. 57 N., R. 76 W.	SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 7, T. 55 N., R. 83 W.	Sec. 14, T. 54 N., R. 83 W.	Kendrick station, sec. 24, T. 55 N., R. 78 W.
Laboratory No.....	5545.	5380.	5382.	5403.	5402.	5546.	5748.	5922.
Sample as received:								
Prox. Moisture.....	23.93	23.54	23.28	28.86	28.55	22.35	24.70	30.32
Volatile matter.....	35.75	34.46	35.47	29.50	29.43	31.41	35.17	30.79
Fixed carbon.....	34.25	37.18	37.34	38.36	38.31	34.70	30.02	31.90
Ash.....	6.07	4.82	3.91	3.28	3.71	11.54	10.11	6.99
Sulphur.....	.82	1.44	.26	.32	.28	2.67	.46	1.25
Ult. Hydrogen.....	6.49			6.31	6.43	5.69		6.36
Carbon.....	50.98			48.66	48.52	47.94		44.76
Nitrogen.....	1.08			.84	.76	1.02		.91
Oxygen.....	34.56			40.59	40.30	31.14		39.73
Calories.....	4,902	5,005	4,923	4,573	4,574	4,572	4,232	4,278
British thermal units.	8,824	9,009	8,861	8,231	8,233	8,230	7,618	7,700
Loss of moisture on air drying.....	8.10	6.90	10.00	12.80	14.20	7.00	15.00	15.30
Air-dried sample:								
Prox. Moisture.....	17.23	17.87	14.76	18.42	16.72	16.51	11.41	17.74
Volatile matter.....	38.90	37.01	39.41	33.83	34.31	33.77	41.38	36.35
Fixed carbon.....	37.27	39.94	41.49	43.99	44.65	37.31	35.32	37.66
Ash.....	6.60	5.18	4.34	3.76	4.32	12.41	11.89	8.25
Sulphur.....	.89	1.55	.29	.37	.33	2.87	.54	1.48
Ult. Hydrogen.....	6.09			5.61	5.65	5.28		5.50
Carbon.....	55.47			55.80	56.55	51.55		52.85
Nitrogen.....	1.18			.96	.89	1.10		1.07
Oxygen.....	29.77			33.50	32.26	26.79		30.85
Calories.....	5,334	5,376	5,470	5,244	5,331	4,916	4,979	5,051
British thermal units.	9,602	9,677	9,846	9,439	9,596	8,849	8,962	9,091

DETAILED DESCRIPTION OF COAL BEDS.

The following brief descriptions of coal are given in order of groups from the base of the section upward. This order of treatment happens to run at the same time from the better-known and more extensively developed coals to those less known and of less value at the present time.

MASTERS COAL BEDS.

The upper of the two Masters coal beds has been exposed in prospect pits and mined at various times for local use at several places in secs. 10 and 14, T. 57 N., R. 85 W. It is reported that both beds have been penetrated by prospect drills at a number of other places in the vicinity. At the base of a small butte in sec. 4, T. 57 N., R. 85 W., the lower bed is exposed as follows:

Section of lower Masters coal bed, in sec. 4, T. 57 N., R. 85 W.

	Ft. in.
Shale, carbonaceous.....	
Coal.....	3
Shale, blue.....	2
Coal.....	6 6
Shale, gray.....	
Total workable coal	6 6

When this field was examined in August, 1907, preparations were being made to develop the upper Masters bed on a commercial scale in sec. 14, T. 57 N., R. 85 W., where a section was made and a sample collected for analysis. An entry had been driven 300 feet at this place.

Section of upper Masters coal in sec. 14, T. 57 N., R. 85 W.

Shale, soft drab.	Ft. in.
Coal.....	4 10
Shale, soft.....	3
Coal.....	11
Shale, soft blue.	
Total workable coal.....	4 10

The Masters coal beds are not positively known except between Tongue River and Slater Creek, in T. 57 N., R. 85 W. One of the beds has been reported in a drill record at the west edge of sec. 24, just south of Tongue River.

A coal thought to be one of the Masters beds has been mined for local use on Soldier Creek, in the SE. $\frac{1}{4}$ sec. 29, T. 56 N., R. 85 W. There was 7 feet 6 inches of coal visible in the drift, and the base of the bed was not exposed. This coal seemed to be equal in quality to the Masters coals on Tongue River.

CARNEY COAL BED.

The Carney coal bed is exposed at only a few places and these are in and north of the Tongue River valley. The best locality is at the Carneyville mines in Carneyville, where extensive mining operations are being conducted. The following are sections of the bed at that place and at Monarch:

Section of Carney coal bed at Carneyville.

Sandstone, white, massive.	Ft. in.
Shale, variable.....	3-6
Coal, upper bench.....	4 6
Shale.....	2-4
Coal.....	10 9
Shale, carbonaceous.	
Total workable coal.....	15 3

Section of Carney coal bed in shaft at Monarch.

Shale.	Ft. in.
Coal.....	4
Shale.....	4
Coal.....	10
Shale, carbonaceous.	
Total workable coal.....	14

The Carney coal is admirably situated for mining just above the Tongue River bottom on the north side at Carneyville, and at a depth

of 86 feet at Monarch, on the south side, where extensive mines are in operation.

The same coal bed is exposed in a couple of prospects on the east side of Slater Creek in sec. 12, T. 57 N., R. 85 W. The one on the south, known as the Conable prospect, has an entry 150 feet in length. The lower bench is 8 feet thick at the face of the entry, as shown by the subjoined section:

Section of Carney coal bed at Conable prospect, in sec. 12, T. 57 N., R. 85 W.

Shale, blue.	Feet.
Coal.....	5
Shale, blue.....	1
Coal.....	8
Shale.	
Total workable coal.....	13

A coal believed to be the Carney bed is 14 feet thick in a gulch near the southwest corner of sec. 35, T. 58 N., R. 85 W. Near the northeast corner of sec. 34 a bed of coal, presumably the Carney bed, is 7 feet thick but within 100 feet thins out.

Reports by drillers prospecting for coal show that the Carney coal bed is 16 feet thick in sec. 9, 17 feet in sec. 15, 16 feet 6 inches in sec. 16, and 16 feet in sec. 17, T. 57 N., R. 84 W.; and 15 feet thick in sec. 25, T. 57 N., R. 85 W.

MONARCH COAL BED.

The thickest coal in the Sheridan field is the Monarch bed, which is nearly 100 feet above the Carney coal, and is mined on a large scale at the town of Monarch. It usually occurs, according to reports of mine operators and prospectors, as a double bed similar to the Carney in the same locality. Its thickness is such that in mining a considerable part of the bed is left for roof. In the mine at Monarch the lower and main bench is massive coal from 18 to 20 feet thick, and is separated from the upper bench by a variable parting of shale. The upper bench is not utilized, and is reported by prospectors to be separated into layers by shale. Unless care is exercised in mining, this upper bench, together with the portion of the lower bench left for roof, becomes a menace, being subject to spontaneous ignition in abandoned and partially closed sections of the workings.

On Goose and Beaver creeks a thick coal bed is mined at several localities to supply local demands. The physical properties of the coal and the character of the contact rocks seem to indicate that it is higher than the Carney and probably referable to the Monarch coal bed as it is known on Tongue River.

Prospects made by Stewart Kennedy on the Monarch bed in sec. 24, T. 57 N., R. 85 W., show a section of coal nearly the same as that at Monarch.

A shallow prospect in the E. $\frac{1}{2}$ sec. 23 of the same township exposes 5 feet of coal in the upper part of the Monarch bed. The mine at Kooi, near the center of the same section, was being driven on the lower 7 feet 6 inches of the same bed in August, 1907, and the operator reported that an equal thickness of coal was left in the roof. The main entry had then been driven but a few hundred feet from the mouth.

Numerous drill holes have been made in prospecting for the Monarch coal on both sides of the Tongue River valley. Some of the records note the presence of this bed as follows:

Thickness of Monarch coal bed in Tongue River valley as shown by drill holes.

	Feet.
T. 57 N., R. 85 W.: SE. $\frac{1}{4}$ sec. 23.....	18
Near center sec. 25.....	29
NE. $\frac{1}{4}$ sec. 26.....	18
T. 57 N., R. 84 W.: SW. $\frac{1}{4}$ sec. 19.....	29
Near SE. cor. sec. 19.....	34
NE. $\frac{1}{4}$ sec. 9.....	20
NW. $\frac{1}{4}$ sec. 10.....	20

At the north side of the Big Goose Creek valley, near the east side of sec. 3, T. 55 N., R. 85 W., a mine known locally as the Black Diamond exposes 12 feet of clean coal underlain by 3 feet 6 inches of coal and shale in thin layers. The same bed has been mined for local use at several places in the vicinity of the Black Diamond mine.

A small mine has been developed by Mr. Moore in the S. $\frac{1}{2}$ sec. 11, T. 55 N., R. 85 W. It is presumed that this is the same bed as that of the Black Diamond mine. The bed is 11 feet thick, but only the lower 9 feet is mined.

In the Beaver Creek mine, in the SE. $\frac{1}{4}$ sec. 14, T. 55 N., R. 85 W., the coal bed has the following section:

Section of coal bed at Beaver Creek mine, in sec. 14, T. 55 N., R. 85 W.

Shale.....	Feet.
Coal.....	6- 7
Shale.....	1
Coal.....	12
Shale, blue.....	
Total workable coal.....	18-19

The upper bench at this mine is left in the roof.

The Black Diamond, Moore, and Beaver Creek mines are operated chiefly in the fall to supply Sheridan with domestic fuel.

DIETZ COAL BEDS.

Three workable coal beds have been located on the east side of Goose Creek from Tongue River southward for a distance of about 3 miles. They are known locally as the Dietz coals because of their

development in and near the town of Dietz, and are designated by numbers from the uppermost downward as Dietz coals Nos. 1, 2, and 3. Stewart Kennedy believes that there is at least one workable bed between the Dietz No. 3 coal and the Monarch bed. This opinion is based on the interpretation of drill records and has not been supported by other evidence. The dip of the rocks eastward from the Monarch mine on Tongue River to the exposure of the Dietz No. 3 coal on Goose Creek is very low and is not considered sufficient to place the Monarch coal more than 120 feet beneath the Dietz No. 3 coal near the mouth of Goose Creek.

The Dietz No. 3 coal bed is exposed in only two prospects near the junction of Goose Creek and Tongue River. Six feet of coal is visible, but at neither prospect is a complete section exposed. Mr. Kennedy, who has prospected this bed, reports its thickness as 14 feet. A report from another source of a drilling in the Goose Creek valley indicates nearly the same thickness for this bed. An outcrop in the SE. $\frac{1}{4}$ sec. 20, T. 57 N., R. 84 W., believed to be in the stratigraphic position of the Dietz No. 3 coal, indicates that the bed is so shaly as to be of no value. An abandoned drift had been driven 80 feet from the surface at the base of a high bluff of Goose Creek, in the NE. $\frac{1}{4}$ sec. 22, T. 57 N., R. 84 W.

The Dietz No. 2 coal bed has received most attention of the three. In 1907 it was being worked on a commercial scale at mine No. 5, in sec. 27, T. 57 N., R. 84 W., in Nos. 2 and 4 mines, at Dietz, and in No. 3 mine three-fourths of a mile south of Dietz. In all these mines it has a thickness of about 8 feet 6 inches. In mine No. 3 the coal has a variable thin parting of shale 3 feet above the base. At the other localities named the coal is not divided by shale.

The Dietz No. 2 coal is also prospected in the bluff of Tongue River, in the SE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 15, T. 57 N., R. 84 W.

The Dietz No. 1 coal has been mined only at Dietz, where a large tonnage has been removed. The following is a section of this bed:

Section of No. 1 coal bed at Dietz.

	Ft.	in.
Shale, gray.....		
Coal.....	2	
Shale, gray.....	1	6
Coal.....	7	10
Shale.....	0-1	
Coal.....	9	
Shale.....		

Total workable coal.....	8	7
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There is a probability that all the Dietz coal beds decrease in thickness toward the south from the vicinity of Dietz. The uplands south of Dietz are well covered with gravel, but the rocks in the bluffs of Goose Creek are fairly well exposed and all the Dietz coals should show west of Sheridan, but no such outcrops have been noted.

SMITH COAL BED.

The Smith coal bed is exposed in the hill 1 mile southeast of Dietz and was being mined in the NE. $\frac{1}{4}$ sec. 10, T. 56 N., R. 84 W., and hauled to Sheridan. A section in this mine follows:

Section of coal at Smith mine, in sec. 10, T. 56 N., R. 84 W.

	Ft.	in.
Shale, blue.....		
Shale, carbonaceous.....	5	
Coal, bony.....		6
Coal.....	4	11
Shale, blue.....	1+	
Sandstone, white.....	20	
Total workable coal.....	4	11

The section of coal at the outcrop southeast of Dietz is essentially the same as at the Smith mine. Neither the Dietz No. 1 nor the Smith coal bed was identified except in the vicinity of Dietz.

OTHER COAL BEDS OF TONGUE RIVER GROUP.

Three outcrops of workable coal beds were noted on Tongue River, near the Wyoming-Montana boundary line, that were not correlated definitely with other coal beds. To judge from the physical properties and the composition of one of the beds they are probably equivalent to the Dietz or Monarch coal. One of these beds has been mined for domestic use in the S. $\frac{1}{2}$ sec. 2, T. 57 N., R. 84 W., by Mr. Evans, who lives in the neighborhood. The following section represents this bed:

Section of Evans coal bed on Tongue River, in sec. 2, T. 57 N., R. 84 W.

	Ft.	in.
Shale, light blue.....	16	
Coal and shale, alternate layers.....	2	10
Coal.....	5	2
Bony shale, thin parting.....		
Coal to level of river.....	9	2
Base of coal bed concealed.....		

Total workable coal exposed..... 14 4

The calorific value of this coal indicates that it is one of the best coals in the district.

The same bed, or one near its stratigraphic position, is exposed in the bluffs of Tongue River near the west side of sec. 6, T. 57 N., R. 83 W., where it shows the following section:

Section of coal in bluff of Tongue River, in sec. 6, T. 57 N., R. 83 W.

	Ft.	in.
Sandstone.....	25	
Shale.....	5	
Coal.....		3
Sandstone.....		6
Coal down to level of Tongue River.....	18	
Base of coal concealed.....		

Total workable coal exposed..... 18

A coal bed near the same geologic position was noted in the east bluff of Tongue River, near the center, of the W. $\frac{1}{2}$ sec. 21, T. 58 N., R. 83 W. A section follows:

Section of coal on Tongue River, in sec. 21, T. 58 N., R. 83 W.

	Ft. in.
Sandstone.....	7
Coal.....	4
Sandstone.....	1
Shale.....	1 6
Coal.....	10-12
Base of coal concealed.	
Total workable coal.....	10-12

ROLAND COAL BED.

The coal next above the Smith coal bed has been mined for domestic use in sec. 25, T. 57 N., R. 84 W., by Mr. Roland. In August, 1907, one entry was abandoned and the roof had fallen. Another has been driven about 60 feet on the upper 7 feet 6 inches of the coal. Across the gulch a complete section of the bed is exposed, showing 13 feet of workable coal.

The Roland coal bed seems to thin out toward the south, like the Dietz coals. A coal bed 2 feet thick, which appears to be equivalent to the Roland bed, has been prospected near the northwest corner of sec. 11, T. 56 N., R. 84 W., one-fourth mile east of the Smith mine.

COAL BEDS OF DOUBTFUL STRATIGRAPHIC POSITION.

A coal bed in about the position of the Roland coal has been mined for local use on Badger Creek, near the northeast corner of sec. 29, T. 58 N., R. 82 W. A drift 30 feet long has been driven on 6 feet of coal in the center of the bed, which is 9 feet thick. The bed here seemed to be homogeneous.

A coal bed similarly situated stratigraphically is exposed at two places on Hanging Woman Creek. One is near the south line of sec. 22, T. 58 N., R. 79 W., and the other near the northwest corner of sec. 3, T. 57 N., R. 79 W. The section of the bed at both exposures is as follows:

Section of coal bed on Hanging Woman Creek, in sec. 22, T. 58 N., R. 79 W.

	Ft. in.
Sandstone, white.....	25
Coal.....	1 3
Shale.....	2
Coal.....	1 7
Shale.....	1 10
Coal.....	11 2
Shale, carbonaceous.	
Total workable coal.....	11 2

Two coal beds were noted in the valley of Hanging Woman Creek in Montana, about 12 miles north of the Wyoming line. J. B. Kendrick has a small mine in sec. 2, T. 8 S., R. 43 E., on a coal bed 11 feet 3 inches thick, with an overlying bench 2 feet thick. This bed is near the stratigraphic position of the Dietz coals, and the physical character and fuel value of the coals are similar. A short drift had been made on 7 feet 3 inches of coal in the lower part of the bed.

Another bed nearly 300 feet lower in the rocks occurs in the bluffs of Hanging Woman Creek, near the north line of T. 8 S., R. 43 E., Montana. Fifteen feet of coal is exposed from the creek bed upward. The upper half of the bed seems to be a fair quality, but the lower part contains partings of bony shale.

A coal bed at about the same horizon is exposed in the bluffs of Powder River in sec. 21, T. 57 N., R. 76 W. Its section is as follows:

Section of coal bed on Powder River, in sec. 21, T. 57 N., R. 76 W.

	Ft.	in.
Shale.....	20	
Coal.....	4	
Shale, carbonaceous.....		6
Coal.....	5	4
Shale, carbonaceous.....		8
Coal.....	22	4
Shale, white.....	10	
Shale, blue to river.....	5	
Total workable coal.....	31	8

This coal is exposed beneath an overhanging bluff and a small quantity of coal has been removed from the lower bench.

Another coal bed of considerable thickness and areal extent has been burned in the bluffs of Powder River, 150 feet above the coal last described. Similar indications of burned coal occur along Hanging Woman Creek above the Kendrick coal from the Wyoming line northward.

COAL BEDS ABOVE TONGUE RIVER GROUP.

Several coal beds of probable commercial value were noted at a number of places between the Tongue River and Ulm coal groups. The coal beds are usually separated into several benches by shale or bands of bony coal. Most of these beds occur high in the rock section and nearer the Ulm coals, which lie above them, than the Tongue River coals, which lie below. The following are sections of coal beds that are known only at the localities specified:

Section of coal bed in SW. $\frac{1}{4}$ sec. 13, T. 57 N., R. 83 W.

	Ft.	in.
Shale, blue and carbonaceous.....	10	
Coal.....	3	
Shale, bony.....		3
Coal.....	2	
Shale, blue.....		
Total workable coal.....	5	

Section of coal bed in SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 7, T. 55 N., R. 83 W.

	Ft.	in.
Sandstone, yellow.....	12	
Shale, blue.....	3	6
Coal, bony.....	3	6
Shale, blue.....	2	
Coal, bony, and silicified wood.....	4	10
Total workable coal.....	4	10

An entry 75 feet long has been driven on the lower bench of this coal, which has been worked for domestic use.

Section of coal bed in SE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 36, T. 56 N., R. 83 W.

	Ft.	in.
Shale, blue, sandy.....	2	
Coal.....	2	
Shale.....		2
Coal, poor.....	1	
Shale.....		6
Coal.....	1	
Shale, carbonaceous.....	2	10
Total coal bed.....	4	

It is possible that the included thin shale shown here may pinch out and that the coal may be workable in this vicinity.

Section of coal bed in NE. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 32, T. 56 N., R. 83 W.

	Ft.	in.
Shale, carbonaceous.....	20	
Coal.....	3	
Shale, carbonaceous.....	3	
Coal, with three thin shale seams.....	5	6
Shale, drab.....	1	
Coal.....	5	
Shale, drab, soft.....		
Total workable coal.....	5	

Section of coal bed in SW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 12, T. 55 N., R. 84 W.

	Ft.	in.
Shale, carbonaceous.....	4	
Coal.....	1	1
Shale, carbonaceous.....		3
Coal.....	1	3
Shale, carbonaceous.....		2
Coal.....		9
Shale, thin seam.....		
Coal.....		5
Shale, bony.....		7
Coal.....		11
Shale, carbonaceous.....		3
Coal.....	1	6
Total coal bed.....	7	2

In August, 1907, this bed was being worked and hauled by citizens for domestic use. The fuel value of the aggregate is evidently low.

Section of coal bed in SW. $\frac{1}{4}$ sec. 21, T. 56 N., R. 82 W.

Shale, carbonaceous.	Ft. in.
Coal, bony, weathered.....	2 2
Shale.....	9
Coal, bony.....	5
Base concealed.	

Section of coal bed near east side sec. 7, T. 56 N., R. 82 W.

Shale.....	Ft. in.
Coal.....	25
Shale.....	3
Coal.....	3
Shale, blue.....	5
Sandstone, white.....	5 6
	10+

Section of coal bed near southwest corner sec. 32, T. 56 N., R. 83 W.

Shale, carbonaceous.....	Feet.
Shale with thin seams of coal.....	50
Coal.....	5
Shale.....	2

Section of coal bed in SW. $\frac{1}{4}$ sec. 31, T. 56 N., R. 79 W.

Shale, blue.	Ft. in.
Coal, shale, and carbonaceous sandstone.....	6 6
Coal, bony and silicified wood.....	2 6
Shale, blue, thin seam.	
Coal.....	33 6
Shale.	

Section of coal bed in NW. $\frac{1}{4}$ sec. 16, T. 56 N., R. 82 W.

Shale, carbonaceous.	Ft. in.
Coal.....	10
Shale.....	6
Coal.....	8
Shale.....	1
Coal.....	2 6
Base concealed.	

Section of coal bed in NE. $\frac{1}{4}$ sec. 23, T. 56 N., R. 82 W.

Sandstone, soft.	Ft. in.
Shale.....	2
Coal, bony, shaly.....	3
Coal.....	7
Bone.....	2
Coal.....	4
Shale.....	3
Coal and bone.....	6
Shale.....	1
Coal.....	6
Bone and shale.....	4
Coal.....	3

In the NW. $\frac{1}{4}$ sec. 25, same township and range, this bed is mainly carbonaceous shale with two thin bands of coal.

Section of coal bed in Kirkman prospect, sec. 26, T. 55 N., R. 80 W.

Sandstone, soft, white.	Ft. in.
Shale, blue.....	6
Coal.....	1
Shale, thin seam.	
Coal.....	2 4
Bone, sandy.....	1
Coal.....	1
Shale.	
Total coal bed.....	4 4

A coal bed of workable thickness is exposed on Clear Creek near the north line of sec. 11, T. 55 N., R. 78 W., east of the area mapped. Ten feet of coal is exposed down to water level. At the time this coal was examined the creek was at flood and the lower part of the bed was concealed. The same coal bed has been prospected with the drill in secs. 23, 24, and 25 and shafts have been sunk to it in the SW. $\frac{1}{4}$ sec. 22 and the NE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 24, T. 55 N., R. 78 W. The following data are reported by J. N. Sweat, who is in charge of the construction of a coal-mining plant at Kendrick station, in sec. 25, T. 55 N., R. 78 W.

Thickness of coal bed in T. 55 N., R. 78 W.

Location.	Opening.	Depth to coal.	Thickness of coal.
		<i>Fect.</i>	<i>Fect.</i>
SW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 22.....	Shaft.....	110	13
Near center W. $\frac{1}{4}$ sec. 23.....	Drill hole.....	116	12
SE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 23.....	do.....	148	12
NE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 24.....	Shaft.....	148	12
SW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 24.....	Drill hole.....	148	12
SW. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 25.....	do.....	180	14
NW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 25.....	do.....	178	12
SE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 26.....	do.....	170	12

On the same authority is given the following record of a well drilled at Clearmont, in sec. 21, T. 54 N., R. 79 W.:

Section of well at Clearmont, sec. 21, T. 54 N., R. 79 W.

	Fect.
Sandstone and shale.....	195
Coal.....	12
Sandstone and shale.....	101
Coal.....	18

No information was obtainable as to the quality of the coal reported in this section.

ULM COAL BEDS.

The presence of the Ulm coal beds is more generally indicated by burned rock than by their exposures. The Upper Ulm coal bed, especially, has been burned very extensively. Complete sections of the Ulm coal beds could be obtained at only a few localities, and these indicate that the beds are usually divided into several benches and that both the individual benches and the beds as a whole vary

in thickness from place to place. The Ulm coals are not mined for commercial purposes and are not taken for local fuel supply except at a few places. The following sections represent the lower bed:

Sections of Lower Ulm coal bed.

SEC. 34, T. 54 N., R. 80 W.		PROSPECT NEAR CENTER OF SEC. 20, T. 54 N., R. 82 W.—Continued.	
	Ft. in.		Ft. in.
Coal with silicified wood	2	Shale, carbonaceous, etc.—Cont'd.	1
Shale	2	Coal	4
Coal	2	Shale, drab.	
	5		
NE. $\frac{1}{4}$ SEC. 30, T. 54 N., R. 80 W.		Total coal bed	5
Shale.	Feet.		3
Coal, with lentils of sandstone and silicified wood	5	NW. $\frac{1}{4}$ SEC. 13, T. 55 N., R. 81 W.	
Coal	5	Sandstone, soft.	Ft. in.
Coal in pit, reported	6	Shale, carbonaceous	4
	16	Coal	7
JACOB LANG PROSPECT, SEC. 3, T. 54 N., R. 80 W.		Shale, thin seam.	6
	Ft. in.	Coal	2
Shale, carbonaceous	1	Shale.	
Coal	2	Total workable coal	9
Shale, thin, carbonaceous, with fossil shells.			6
Coal	4	BETHEUREM PROSPECT, SEC. 14, T. 54 N., R. 83 W.	
Coal, bony, base of bed concealed.			Ft. in.
Total coal	6	Shale, carbonaceous	9
PROSPECT NEAR CENTER OF SEC. 20, T. 54 N., R. 82 W.		Shale, with thin coal seams	5
	Ft. in.	Shale, blue	1
Shale, carbonaceous, and thin coal.	7	Coal, bony	2
Coal, with two thin shale seams	2	Shale, drab	6
Shale, carbonaceous	3	Coal, bony	2
Coal	1	Shale, carbonaceous	6
Shale, thin parting.		Coal	1
		Shale, blue	4
		Coal, bony	2
		Total coal bed	6
			2

The shale bands in the section at the Bethourem prospect are variable both in composition and thickness. The lower 5 feet 4 inches of coal was being mined for domestic fuel. The shale seams were rejected in mining.

Six feet of the Lower Ulm coal bed is exposed in a prospect pit in the SW. $\frac{1}{4}$ sec. 34, T. 54 N., R. 81 W., but the lower part of the bed is concealed. The same condition also prevails near the south side of sec. 23, T. 54 N., R. 82 W., where 5 feet of the upper part of the bed is exposed. Four feet of good coal in the upper part of the Lower Ulm bed was exposed near the southwest corner of sec. 6, T. 54 N., R. 80 W.

In a prospect pit on the Lower Ulm coal bed in the SE. $\frac{1}{4}$ sec. 30, T. 54 N., R. 80 W., 4 feet 6 inches of coal is exposed, the lower part of the bed being concealed.

The following sections represent the upper bed of the Ulm coal group:

Sections of Upper Ulm coal bed.

NEAR CENTER OF EAST SIDE SEC. 33, T. 54 N., R. 80 W.		OUTCROP NEAR CENTER OF EAST SIDE SEC. 13, T. 56 N., R. 82 W.	
Shale.	Ft. in.		Ft. in.
Coal.....	3	Shale, carbonaceous, with many thin seams of coal.....	20
Shale, carbonaceous.....	3	Coal.....	5
Coal.....	4	Shale.....	4
Shale.....	2	Coal.....	1
Coal.....	5	Shale.....	5
Coal, bony to base of exposure..	4	Coal.....	1
Total workable coal.....	12	Shale, carbonaceous.....	
		Total coal bed.....	7 9

Three feet of coal that is considered to be the central part of the Upper Ulm bed is exposed in a natural outcrop near the northeast corner of sec. 12, T. 54 N., R. 81 W.

DEVELOPMENT.

Coal mining in the Sheridan district, except for local domestic fuel, is restricted to the coal beds of the Tongue River group on Goose Creek and Tongue River. The thriving mining communities of Dietz, Carneyville, Monarch, and Kooi are an index to the rapid growth of the coal-mining industry. The following information in regard to the development of the field is obtained from an article by Stewart Kennedy ^a and from field work in 1907.

As early as 1880 coal of workable thickness was known and mined for domestic use by ranchmen at the present location of Dietz. From this time on to 1893, when the first commercial mining began, coal from several prospects on what are now known as the Dietz coal beds Nos. 1 and 2 was mined and hauled to Sheridan. A drift was run on the Dietz No. 1 coal near the east side of sec. 34, T. 57 N., R. 84 W., in the winter of 1892-93 and the first shipment of coal was made in the following May. Operations continued until 1899, the coal being mined by pick and hoisted by mule power. A modern steam plant was erected in 1899 for the development of mine No. 1 and the output was greatly increased. A shaft was put down in 1900 in sec. 35, T. 57 N., R. 84 W., to the Dietz No. 2 coal bed and the development of mine No. 2 began with the erection of a complete hoisting plant and shops. Later a large electric plant was built and machine mining and electric haulage were established in the Dietz mines. In 1903 a shaft was sunk on the Dietz No. 2 coal bed in sec. 3, T. 56 N., R. 84 W., and a modern hoisting plant established as mine No. 3. Also a slope was

^a Mines and Minerals, vol. 27, 1907, pp. 294-297.

driven on coal bed No. 2 in Dietz and a drift on the same bed $1\frac{1}{2}$ miles north of Dietz, with adequate equipments, as mines Nos. 4 and 5, respectively. These mines at and near Dietz, operated by the Sheridan Coal Company, employ at the present time about 800 men and support a population of about 2,000 persons.

A slope mine was opened in 1904 by the Wyoming Coal Mining Company on the Monarch bed at the west side of sec. 19, T. 57 N., R. 84 W., and a complete modern equipment for extensive mining, including electric power, was installed. This plant employs about 325 men and the town of Monarch, established here, has a population of nearly 700. Recently a shaft has been sunk at the Monarch mine 86 feet to the Carney coal bed. Both the Monarch and Carney beds, with an aggregate of at least 34 feet of clear coal, will be exploited at this plant.

The Carney Coal Company opened mines on the Carney coal bed on the north side of Tongue River, near the southeast corner of sec. 17, T. 57 N., R. 84 W., in the latter half of 1904. A modern equipment for mining, hauling, hoisting, and loading coal, including an electric plant, was erected on the south side of the river. The mine is driven north of west on the rise of the coal bed. Later a second mine was opened adjoining the first on the same bed, in the SW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 16, and recently a second tippie was erected to accommodate the increased output. The mining town of Carneyville has a population of approximately 1,400, and the company employs about 500 men.

The mining town of Kooi was established in the N. $\frac{1}{2}$ sec. 23, T. 57 N., R. 85 W., during 1907, and a slope mine was driven on the Monarch coal southward from the outcrop. The village is reported to contain 100 inhabitants, with about 75 men employed in mining operations. A spur connects the mine with the Chicago, Burlington and Quincy Railroad on the north side of Tongue River.

Late in the season of 1907 the Riverside Coal Company began operations on the Upper Masters coal bed in sec. 14, T. 57 N., R. 85 W., but the extent of the development is not reported. A mining plant was in process of construction at Kendrick station, in sec. 25, T. 55 N., R. 78 W., by the Wyoming Smokeless Coal Company, for the exploitation of a 12-foot coal bed.

UTILIZATION AND MARKET.

Prior to 1900 the Sheridan coals were used principally for domestic fuel. They were not regarded as successful for steaming purposes, especially where strong drafts and small fire spaces were used. The difficulties with the use of this coal for steaming, especially in locomotives, seemed to be due to the decrepitation of the fuel when

suddenly heated. The small particles of coal that are thrown off by the sudden application of strong heat are in large part either blown out of the stack or fall between the grate bars used in the ordinary fire box of locomotives and other engines.

The Burlington Railroad began a series of tests of the Sheridan coals in its locomotives in 1900. By the use of specially constructed grates of large area, with modified fire boxes and stacks, the Sheridan coal is said to produce very satisfactory results. Coal from all the beds now mined is used extensively in locomotives and stationary engines.

A large part of the production of coal in the Sheridan district is used by the Burlington Railroad. It is marketed in Wyoming and Nebraska as far east as Omaha; in the Black Hills region; at Billings, Butte, and other points in Montana, and as far west as Idaho and Washington.

THE GLENROCK COAL FIELD, WYOMING.

By E. WESLEY SHAW.

INTRODUCTION.

The Glenrock coal field, in the east-central part of Wyoming, comprises the southern end of a great area of coal-bearing rocks, the Fort Union region, which covers the northeastern part of Wyoming, most of the eastern half of Montana, and the western half of North Dakota. (See fig. 4.) The principal towns in this field are Casper

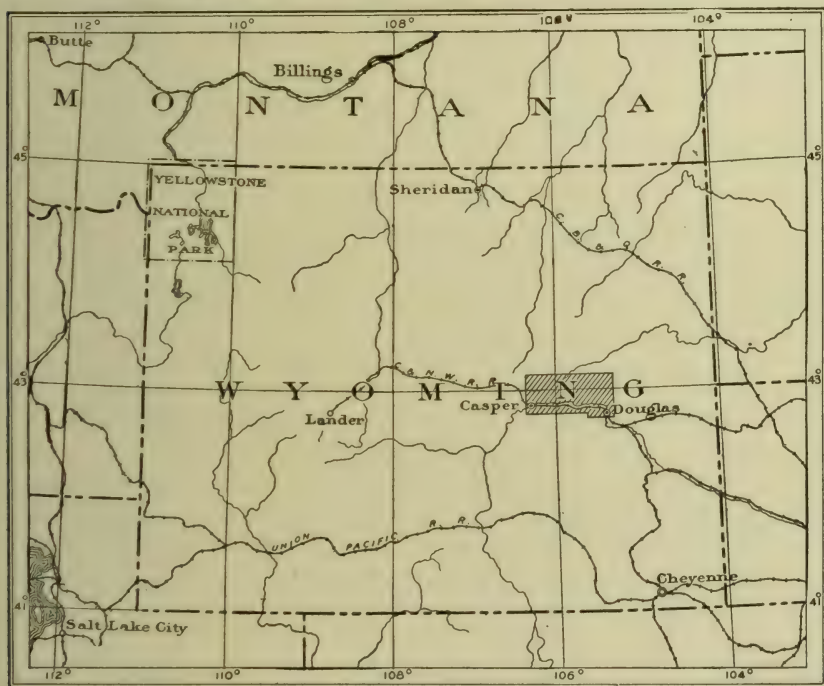


FIG. 4.—Index map showing location of Glenrock coal field, Wyoming.

and Douglas, each having about 1,000 inhabitants and being the center of an extensive stock-raising community. There are also three or four smaller towns along the line of the Chicago and North-western Railway, the most important of which in regard to coal mining is Glenrock. The field described in this report is nearly rectangular, with Douglas near the southeast corner and Casper near the southwest corner. It is about 56 miles east and west by 27 miles north and south, and comprises an area of about 1,512 square miles.

The field lies at the foot of the front range of the Rocky Mountains, at the point where it changes in trend from the long north-south course across Colorado and the southern part of Wyoming to an east-west course of 50 miles parallel with and on the south side of North Platte River. At the west end of this 50-mile stretch the range as such disappears, but farther north it is represented by the Bighorn Mountains, which are similarly situated with reference to the coal fields on the east. About three-fourths of the Glenrock field lies on the north side of North Platte River.

The work of which this paper is a report was of a reconnaissance character, and on the west and south it was carried to the limits of the coal-bearing rocks. The eastern and northern boundaries of the field as mapped are arbitrary, depending principally on the amount of time at the disposal of the party. East of the field the coal-bearing formations are partly covered with barren Tertiary rocks, but toward the north they are found at the surface almost without interruption for hundreds of miles.

The writer was assisted by Charles T. Lupton, E. H. Sirich, R. A. Branson, and A. S. Ogle. As the work was primarily one of land classification, it was necessary to retrace the lines of the old land survey and locate the outcrops of the coal beds with reference to the corner stones established by that survey. The other features of the country were located also by their distance and direction from the land corners. The exact astronomic location of the land lines is not known.

TOPOGRAPHY.

The surface of the country is hilly, but not mountainous. It is generally possible to drive wherever one desires, whether there is a road or not. Near the mountains the country is essentially a plain that has been deeply dissected by the streams, leaving mesas sloping gently toward the north or away from the mountains. Farther away from the mountains the country is gently rolling, with a few flat-topped hills, but there are a few small areas of rough country where the mantle of Tertiary and Quaternary material is removed, revealing the presence of the lower and more indurated rocks. A rather unusual feature is that much of the field is covered with sand dunes.

North Platte River flows eastward across the field, and there are five bridges across it. It is seldom that the stream can be forded except late in summer, but at that time it may be crossed at a great many places. There are very few other perennial streams, and most of these are on the south side of the river and owe their existence to the mountains. North of the river water is scarce and the quality is very poor. There are some "alkali seeps" where water may be had at any time of the year by digging a shallow well, but to get good water it would generally be necessary to drill a thousand feet or more. Casper, Douglas, and all the smaller towns and post-offices are situa-

ted along North Platte River, and the Chicago and Northwestern Railway runs through these towns, mostly in the bottom land of the river.

Throughout a considerable part of the field the building of first-class roads would be difficult on account of the sandy nature of the soil. There is no other route so well adapted to railroad building as the river valley, but it would be possible to build a railroad to any point, as the country as a whole is not rough, and cuts and fills could be made without the excavation of much rock. The main obstruction to a north-south railroad is the divide between North Platte and Powder rivers, which, however, presents no great difficulty, as it is only 500 to 1,000 feet higher than the valley of the North Platte.

GEOLOGY.

STRUCTURE.

The structure is dominated by the uplift of the Rocky Mountain front range on the south and a slight uplift on the west. The strata dip, in general, north at the east end of the field and northeast at the west end, so that the structure, as a whole, is that of a broad, shallow syncline pitching to the northeast. In a belt 6 or 8 miles wide, lying along the foot of the mountains, the average dip is 15° , but it varies greatly in this belt, as does also the strike. Along the southern border of the field the strata in this belt are commonly upturned very steeply, but farther from the mountains the strata are almost horizontal. No great faults affect the area of coal-bearing rocks, though there are probably numerous small ones. For example, there is one in the Glenrock mine which has a throw of 8 feet.

STRATIGRAPHY.

GENERAL SECTION.

The following formations occur in the Glenrock field (see also columnar section on map, Pl. IX).

Quaternary: Wind-blown sand, rain wash, mesa and terrace gravel, lake beds, and flood-plain deposits.

Tertiary:

Red and light-gray conglomerate and sandstone.

White clay, more or less calcareous and commonly sandy (White River formation).

Fort Union (?) formation (shales, sandstones, and coal).

Cretaceous:

Montana—upper two-thirds principally sandstone with coal; lower third dark shale with no coal.

Colorado—mostly dark-brown shale with some brown sandstone layers, and at the top a buff to white sandstone, which may be Niobrara. Near the base is the Mowry member, a very resistant dark shale which weathers white.

Cloverly—massive, brown, resistant sandstone, which commonly forms a pronounced hogback. Near the top there is some shale, and at the bottom a fine conglomerate.

MONTANA, OR LOWEST COAL-BEARING FORMATION.

The subjoined generalized section of the Montana formation is representative of its character in the Glenrock field.

Generalized section of Montana formation.

	Feet.
12. Sandstone, with numerous hard layers and some beds of shale.....	200
11. Shale, sandy, locally carbonaceous.....	125
10. Sandstone, white, marly or argillaceous.....	50
9. Sandstone, brown, lower part massive, upper part more thinly bedded, medium grained; has numerous worm or lamellibranch borings, rather resistant to weathering.....	575
8. Shale, dark, uniform in color and texture.....	475
7. Sandstone, white, massive, the most resistant member of the Montana; includes one or two beds of coal.....	120
6. Shale and sandstone alternating.....	510
5. Shale, sandy.....	280
4. Coal, one or two beds, total thickness.....	4±
3. Sandstone, white, argillaceous, with two layers of very resistant dark-brown sandstone forming hogback with characteristically irregular crest.....	110
2. Shale, sandy, with several layers of sandstone.....	800
1. Shale, sandy.....	1,800
	5,049±

The character of any particular member is fairly constant, though the color, composition, and thickness of the beds composing it change from place to place. Exposures 50 feet apart on the outcrops of a single layer 2 or 3 feet thick are commonly so different in appearance that it is difficult to recognize them as the same bed.

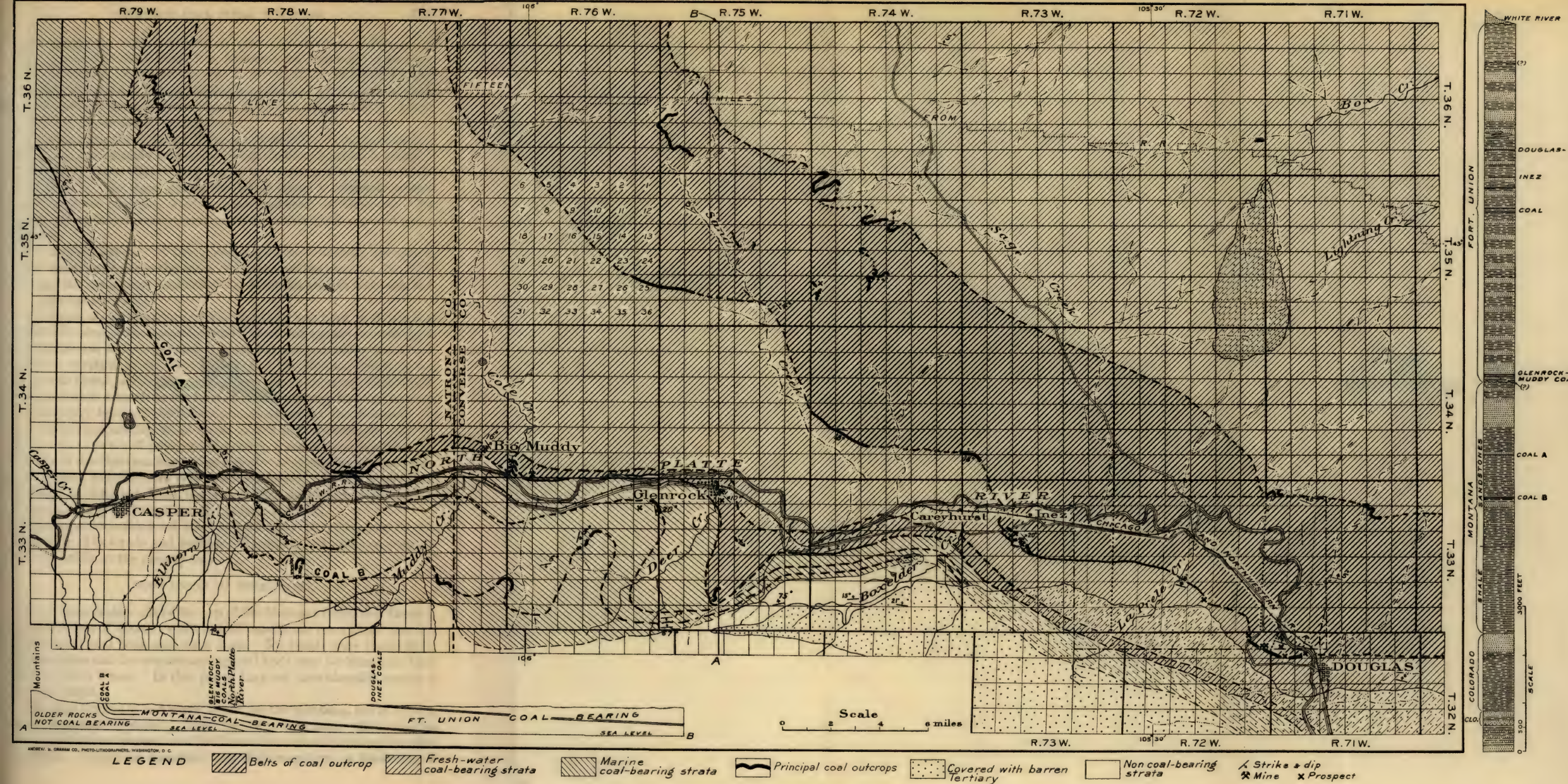
The lowest member of the Montana may be recognized by its position just below the coal-bearing rocks and above older noncoal-bearing formations, also by its physical character. It is composed of uniformly dark shale 1,800 feet thick, containing numerous more or less round concretions. The outcrop of the shale forms a belt along the south side and west end of the coal field, including the area in which the town of Casper is located.

The next member (No. 2 in the section given above) contains several beds of sandstone. Otherwise it resembles the member just described.

The third member commonly forms a hogback with a very ragged crest of dark-brown sandstone. The white parts of the member, being less resistant, are not so prominent.

Just above this sandstone is a bed or two of coal (bed B on the map, Pl. IX). The overlying shale (No. 5) is sandy, and is much like member No. 1, but its outcrop is generally covered with soil, and the details of its composition are unknown. There are local exposures of parts of the sixth member, but the seventh is the most resistant and





consequently the most conspicuous part of the whole section. At many places it forms a large, low, pine-covered hogback. One very good exposure is located in sec. 16, T. 33 N., R. 78 W., 6 or 7 miles southeast of Casper. This sandstone contains one or two beds of coal, and its outcrop agrees approximately with that of coal bed A, which crosses sec. 16, as shown on the map.

In going from the resistant white sandstone (No. 7) in the direction of the dip, one usually crosses a broad, shallow depression which is underlain by shale (No. 8) and comes to an outcrop of brown sandstone (No. 9). In some places the latter forms a hogback several miles long, for example, 6 or 8 miles southeast of Glenrock. Its weathered surface is everywhere much smoother than exposed parts of No. 3.

The upper boundary of the brown sandstone is usually indistinct, as the brown grades into the white of the succeeding member (No. 10). This and the remaining members of the Montana are not resistant, and few outcrops are visible.

The exact upper boundary of the Montana was hard to determine in the field because the strata known to be of this age are overlain by a nonfossiliferous sandstone which is much like the beds below and which in turn is overlain by the Fort Union (?). No distinct stratigraphic break was found, although in one or two places there are slight indications of such a break at the base of this sandstone, and on the map the boundary between the formations is drawn at this horizon. It may, however, possibly be as much as 400 feet stratigraphically, or one-fourth to one-half mile on the surface, from its true position.

Parts of the Montana formation contain many shells and other animal remains, but there are very few fossil leaves. In this respect the Montana is different from the succeeding coal-bearing formation, which has many leaf imprints and almost no shells.

The upper two-thirds of the Montana may be equivalent to the Mesaverde of Colorado and southern Wyoming, but exact correlation is not possible at the present time.

FORT UNION (?) FORMATION.

At or immediately above the top of the Montana formation there is about 400 feet of massive white or buff sandstone (mentioned above), with several coal beds and some shale. No fossils were found in it. This member and the accompanying coal beds may be Montana, Laramie, or Fort Union. In this paper they are provisionally regarded as Fort Union.

The Fort Union (?) as a whole resembles the Montana, but it is even more irregularly bedded. There are very few zones which can be recognized wherever seen, and the formation is much thicker than the Montana. It may be separated into three members—a lower one of

white to brown sandstone, already described, which is best exposed near Glenrock and on Cole Creek near Big Muddy; a middle member, which underlies a large area north and northwest of Douglas and is made up of dark shale and sandstone; and an upper member of bluish shale which weathers white and outcrops in a small area on the north side of the Glenrock field.

The central part of the Fort Union (?) is a great mass of dark shale, much of it carbonaceous, but it contains also light shale, sandstone, and some coal beds. Near the top is a zone of loglike concretionary masses, the origin of which is not well understood. They are found in greatest abundance 6 to 10 miles north of Douglas.

Near the middle of the north side of the field there are outcrops of very light beds consisting of shale and some sandstone, which do not appear elsewhere in this field. The weathered surface of the shale is white, but the unweathered parts are blue. No coal was found in this member, and it is thought to constitute the top of the Fort Union (?) section.

FORMATIONS ABOVE THE COAL.

The coal-bearing rocks described above are unconformably overlain by Tertiary and Quaternary formations. The White River, a Tertiary formation of white sandy clay and conglomerate, covers a considerable area in the southeastern part of the field. It is spread over parts of all the older formations, and is even found high up in the mountains. The so-called Chalk Buttes, 3 miles southwest of Douglas, are also composed of Tertiary rocks, and the outcrop of similar rocks extends westward for 25 miles along the foot of the mountains.

The irregular areas of sand dunes which cover a large part of the field obscure the geology of the rocks below. Some whole townships are covered to a depth of 1 to 200 feet, the average thickness of the sand being about 25 feet. Here and there among the dunes are outcrops of coarse sandstone, and it seems probable that this rock is of Tertiary age, and that the sand is the result of its disintegration.

Red conglomerate of Tertiary age occurs on the mesa 15 miles north of Douglas. This is an isolated deposit and can not be correlated with other rocks in this field of the same general age.

A gray Tertiary conglomerate occurs in the valley of the North Platte 10 to 150 feet above the river, but it is not extensive and hence is not an important consideration in coal mining.

The Quaternary formations consist of the sand just mentioned, gravel deposits on mesas and terraces, rain wash, and stream deposits. Rain wash is of much importance in this field, for it obscures the bed rock and reduces the number of exposures. There are large areas of gently rolling country where the products of weathering completely cover the underlying rocks. In such places, as in the sand areas, the

position of geologic boundaries could not be determined, and lines on the map referring to bed rock are broken because of this uncertainty.

The mesa and high-terrace gravel deposits are usually less than 25 feet thick, but in the process of erosion the gravel is let down as a mantle on the sides of the mesas. Many hills that are largely composed of coal-bearing rock appear to be solid gravel because of this mantle.

THE COAL.

HISTORY OF DEVELOPMENT.

The oldest mines in the field are at Glenrock and near Douglas. They were opened about 1883. The Inez mine was opened in 1888 by Governor J. D. Richards and Messrs. Chamberlain and Vosbergh. The Big Muddy mine was opened by Messrs. Tracey and Veitch in 1900. Coal declaratory statements have been filed on many tracts of land, and some have been taken up in other ways because of their coal-producing possibilities. Much of this was done in 1887, when the railroad was first put in operation. At that time many new mines were opened and coal mining received a great impetus, but most of the beds were found to be too thin or too poor to be worked with profit, and as a result final proof was not made on many of the tracts, and they reverted to the public domain. The only productive mines at present are the Glenrock and the Big Muddy.

COAL BEDS OF THE MONTANA FORMATION.

Workable coal beds occur in members Nos. 4 and 7 of the section on page 154. The coal is of fair quality compared with other Wyoming coals, but the beds are generally too thin to be worked with profit. The greatest thickness observed was scarcely 4 feet.

The coal in member No. 4 is worked 7 to 10 miles southeast of Casper, on and near Nicholaysen's ranch. The workings consist of a dozen or more drifts, some of which have been driven 100 feet into the hillsides. The coal has been stripped where it outcrops at Weber's ranch, southwest of Big Muddy, and a little is obtained from the outcrop in the north bank of the river, 3 miles east of Casper, but it is not worked elsewhere in the field. The thickness of the coal beds of this lower zone ranges from 2 to 4 feet.

The uppermost coal beds of the Montana formation occur in the resistant white sandstone (No. 7), which is exposed in many places; consequently the coal is comparatively easy to locate. In Tps. 34, 35, and 36 N., Rs. 79 and 80 W., there is a long and almost continuous outcrop of the sandstone, but the full thickness is not exposed in any one place. In many localities the coal associated with the sandstone is not visible, but it is probable that one or more coal beds 2 to

3 feet thick are present wherever the sandstone occurs. The following is a typical section:

Section of coal beds in white sandstone on north side of North Platte River, 4 miles east of Casper.

	Ft. in.
Shale, carbonaceous.....	3
Sandstone, yellowish white.....	6
Coal.....	2
Sandstone, white.....	25
Coal.....	2 10
Sandstone, white.....	3
Shale, sandy, carbonaceous.....	6
	47 10

COAL BEDS OF THE FORT UNION (?) FORMATION.

The Fort Union (?) formation contains two coal zones of importance and traces of coal at a number of other horizons. The most extensive coal mining of the region is being done on the beds of the Big Muddy-Glenrock zone, at the base of this formation. The coal beds are probably not identical at these two places, but they occur in the same zone and are not far apart stratigraphically. At Big Muddy two beds are worked, one 4 feet 8 inches thick and the other 3 feet 6 inches. At Glenrock only one bed is worked to any extent; it is more than 5 feet thick. The localities where the coal belonging to this zone may be seen are shown on the map (Pl. IX). One very good outcrop is on Cole Creek, in sec. 31, T. 34 N., R. 76 W. Another is on the north bank of the river, near the southwest corner of T. 34 N., R. 75 W. In the southeastern part of the field this coal is covered with the white Tertiary clays and conglomerate to a depth of 1 to 600 feet. The following section, showing the coal beds in this zone, has been furnished by the Glenrock Coal Company:

Section showing strata passed through by diamond drill at the northeast corner of the SE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 4, T. 33 N., R. 75 W., Glenrock, Wyo.

	Ft. in.
Surface soil.....	3
Sand and gravel.....	7
Shale, sandy.....	28
Sandstone, soft.....	9 10
Shale, sandy.....	41 10
Soapstone.....	8 2
Sandstone.....	2
Soapstone.....	3
Sandstone.....	5 8
Slate, black.....	4
Coal.....	2
Coal, bony.....	2
Fire clay.....	4
Sandstone, hard.....	8

	Ft. in.
Shale, gray.....	2
Coal.....	3
Fire clay.....	6
Shale, sandy.....	1 7
Sandstone, soft.....	21
Shale, gray.....	9 2
Shale, brown.....	8
Shale, black.....	9
Shale, gray.....	9
Shale, brown.....	4
Shale, black.....	8
Shale, sandy.....	2
Sandstone, soft.....	18
Sandstone, hard.....	1 2
Shale, sandy.....	14 5
Shale and trace of coal.....	1 4
Shale, gray.....	9
Sandstone, hard.....	3
Shale, gray.....	9 3
Iron rock.....	1 8
Shale, sandy.....	6 2
Sandstone, soft.....	10 10
Sandstone, hard.....	1
Sandstone, soft.....	18 5
Shale, brown.....	1
Coal.....	7 6
Fire clay.....	6
Soapstone.....	10 4
Shale, gray.....	1 6
Coal.....	2 2
Fire clay.....	4
Sandstone, soft.....	52 8
Sandstone, hard.....	1 6
Sandstone, soft.....	12
Sandstone, hard.....	1 6
Sandstone, soft.....	34
Shale, sandy.....	5
Sandstone, soft.....	21 4
Sandstone, hard.....	1 4
Sandstone, soft.....	68 4
Coal.....	1 1½
Fire clay.....	6
Slate, black.....	4 10
Coal.....	8
Fire clay.....	4
Slate, black.....	1 8
Slate, gray.....	3
Slate, black.....	6
Slate, gray.....	2
Shale, black.....	7
Sandstone, hard.....	1
Soapstone, gray.....	2 6
Shale, gray.....	5 7
Coal.....	5

	Ft.	in.
Fire clay.....		6
Shale, gray.....	1	
Shale, brown.....		6
Coal.....		5
Fire clay.....	1	
Shale, gray.....	12	1
Coal.....		5
Fire clay.....		3
Shale, light colored.....	11	6
Coal.....		8
Fire clay and black shale.....		6
Shale, gray.....		2
Shale, brown.....		3
Shale, sandy.....		5 6
Sandstone, soft.....	82	11
	652	4½

The next coal zone above the Glenrock-Big Muddy is about 2,500 feet above the base of the Fort Union (?) formation. It is about 1,000 feet thick, and will be called the Douglas-Inez coal zone, because Douglas and Inez are the most important places where the beds are worked. It outcrops in a broad belt running from a point near the southeast corner of the field to the north side of T. 36 N., R. 76 W. Near Inez there are two beds of coal, each more than 5 feet thick, and the property would seem to be the most valuable in the area; but the company which undertook to work them did not make a success. The reasons assigned were that (1) the roof and floor are very poor, (2) there was much water, and (3) the coal is not of very good quality. There were three mines on the two beds only a short distance from the railroad, and the coal was worked out for several hundred feet down the dip. A railroad spur was built out to the mines, but mining was abandoned some years ago and the track has been removed.

There are several thinner beds of coal near the two above mentioned, but elsewhere in the field there are not so many beds in this zone. The following is a section near Inez:

Section of Douglas-Inez coal zone 2 miles southwest of Inez.

	Ft.	in.
Sandstone, brown, very resistant.....	3	
Shale, alternating dark and light.....	240	
Shale, sandy, yellowish white.....	15	
Sandstone, hard, dark brown, concretionary.....		4-10
Shale, bluish, light to dark.....	12	
Coal (leaves in roof).....	3	
Sandstone, massive, white, soft.....	4	
Shale, dark, carbonaceous, traces of coal.....	4	
Sandstone, massive, white, rather soft.....	18	
Coal.....	2	11

	Ft.	in.
Shale, dark.....	29	
Shale, blue.....	6	
Coal.....	2	2
Shale, with hard concretionary layers, weathering to very dark brown.....	11	
Shale, light gray.....	4	
Concretions, hard, dark brown.....		1-12
Shale, bluish, massive.....	10	
Shale, thin bedded.....	1	
	365+	

The outcrop of the beds at Inez trends about northwest and southeast, but a short distance farther southeast the trend changes to nearly east and the beds, crossing the river near Douglas, continue in this direction to the east end of the field. Just west of Douglas there are six or eight coal prospects, none of which is worked to any extent at present. The bed ranges in thickness from a little over 2 to a little over 3 feet.

Northwest of Inez the beds are exposed almost continuously to the river. About 1 mile north of the river they probably swing around to the west for a few miles, and then the outcrop trends in a general northwesterly direction to the north side of the field. The coal-bearing zone outcrops only here and there north of the river, and there are few, if any, prospects except those at Inez.

QUALITY OF THE COAL.

The coals found in the region between Casper and Douglas are all classed as subbituminous ("black lignite"), but some are almost good enough to be called bituminous. They are placed in the lower class because all yield rapidly to weathering, through loss of moisture on exposure to the atmosphere, and because bedding planes are very conspicuous, showing that the coal has not reached an advanced stage of metamorphism. The development of joints varies greatly and the fracture is hackly to conchoidal. The coal is black, but when it is exposed to the weather it cracks and the surface becomes slightly brown. At the mines piles of slack take fire spontaneously; however, it is believed that the coal does not slack so readily or take fire so easily as that found 100 to 150 miles to the north. The table of analyses shows that the moisture content of air-dried samples ranges from 13.50 to 20.94 per cent, and also that in a general way the amount of moisture varies with the geologic age of the coal, the youngest having the most moisture.

The samples were not selected lumps of coal, but contained coal from all parts of the bed, so that the analyses show the composition of the average output. To this end nothing was excluded from the samples except such partings as are excluded in mining. Unfor-

tunately, there are only a few places in the area where fresh samples could be obtained. On account of the weathered condition of the coal many of the samples are low in heating value, yielding only a little over 5,000 British thermal units. The two samples from the Glenrock-Big Muddy zone which run over 9,300 British thermal units were quite fresh.

Analyses of coal samples from the Glenrock coal field, Wyoming.

[F. M. Stanton, chemist in charge.]

Geologic formation....	Fort Union (?).								Montana.		
Name of coal zone.....	Douglas-Inez.				Glenrock-Big Muddy.				Resistant sandstone.	Low-est.	
Laboratory No.....	a 5318	a 5317	a 5321	a 5422	5325	5326	5330	5322	a 5320	a 5323	a 5319
Sample as received:											
Prox. { Moisture.....	22.92	20.44	37.86	35.01	22.87	22.87	21.90	19.92	15.58	19.17	19.83
Prox. { Volatile matter.....	42.62	30.49	29.08	28.46	48.03	33.89	34.05	49.25	23.28	26.17	41.39
Prox. { Fixed carbon.....	22.25	18.68	22.37	28.82	20.54	36.71	37.38	20.25	22.68	17.54	26.21
Prox. { Ash.....	12.21	30.39	10.69	7.71	8.56	6.53	6.67	10.58	38.46	37.12	12.57
Prox. { Sulphur.....	.58	.43	.35	.28	.52	.97	.86	.68	1.17	.52	.72
Ult. { Hydrogen.....								5.39		3.85	
Ult. { Carbon.....								51.96		30.68	
Ult. { Nitrogen.....								.60		.56	
Ult. { Oxygen.....								30.79		27.27	
Calories.....	4,071	3,136	2,861	3,295	4,679	4,956	5,040	4,851	2,941	2,718	4,581
British thermal units	7,328	5,645	5,150	5,931	8,422	8,921	9,072	8,732	5,294	4,892	8,246
Loss of moisture on air drying.....	4.30	5.30	21.40	23.30	4.40	4.20	3.30	1.50	2.40	5.30	2.00
Air-dried sample:											
Prox. { Moisture.....	19.46	15.99	20.94	15.27	19.32	19.49	19.23	18.70	13.50	14.65	18.19
Prox. { Volatile matter.....	44.53	32.19	37.00	37.11	50.24	35.37	35.21	50.00	23.85	27.63	42.23
Prox. { Fixed carbon.....	23.25	19.72	28.46	37.57	21.49	38.32	38.66	20.56	23.24	18.52	26.75
Prox. { Ash.....	12.76	32.10	13.60	10.05	8.95	6.82	6.90	10.74	39.41	39.20	12.83
Prox. { Sulphur.....	.61	.45	.45	.37	.54	1.01	.89	.69	1.20	.55	.73
Ult. { Hydrogen.....								5.30		3.44	
Ult. { Carbon.....								52.75		32.40	
Ult. { Nitrogen.....								.61		.59	
Ult. { Oxygen.....								29.91		23.82	
Calories.....	4,254	3,312	3,640	4,296	4,894	5,173	5,212	4,925	3,013	2,870	4,675
British thermal units	7,657	5,961	6,552	7,733	8,810	9,312	9,382	8,865	5,424	5,166	8,414
Thickness of coal bed..	<i>ft. in.</i> 1 10	<i>ft. in.</i> 4 2	<i>ft. in.</i> 1 8	<i>ft. in.</i> 2 6	<i>ft. in.</i> 3 6	<i>ft. in.</i> 4 8	<i>ft. in.</i> 5 6	<i>feet.</i> 6	<i>feet.</i> 3	<i>ft. in.</i> 1 10	<i>feet.</i> 3

a Weathered sample.

There is much less variation in quality than the above analyses would indicate, but it seems probable that coals of the Fort Union (?) formation are slightly inferior to those of the Montana. The latter are blacker, more brittle, lustrous, and clean. Of the Fort Union (?) coals, those at the base, in the Glenrock-Big Muddy zone, seem to be the best.

METHOD OF WORKING.

So far mining has been carried on by beginning at the outcrop and following the coal down the dip to the north or northeast. It may be that in the future, when coal is more valuable and the parts near the outcrop are worked out, shafts will be sunk back from the outcrop and the coal worked up the rise.

At many places in the field coal is mined for local consumption by stripping. The comparatively thin beds which are common in this field are much more easily worked by stripping and in small mines than they are some distance below the surface.

A very common class of coal workings comprises those in which coal is taken out through slopes 10 to 200 feet long. These workings have been made principally for prospecting. In most of them it was hoped that better coal or more of it would be reached by drifting in on the bed, but generally it was found that the coal beds were not thick enough to be worked with profit.

There are two mines which use steam power, the Glenrock and the Big Muddy. The Inez mine also used steam when it was being worked. In most of the mines the main gangway is driven down the dip, and entries are driven from this gangway on each side, rooms being turned off up the rise of the bed. Thus, the Big Muddy mine has been worked down the dip for about 1,000 feet, and has three entries on each side which are 800 to 1,000 feet long. The Glenrock mine has two openings, one down the dip for 3,000 feet and the other nearly on the strike for about 1,200 feet.

The deepest part of the Glenrock mine is more than 200 feet below the surface, and it is nearly under the river. This necessitates constant pumping. A bore hole has just been put down to the deepest part of the mine, to be used in pumping water. The Glenrock Company has an air-compressing plant and fan. Mining is done by undercutting with a machine, and then breaking the coal down with picks. From the rooms the cars are hauled to the main gangway by mules, and thence to the surface by cable.

The Big Muddy Company uses a similar room and pillar system; but at Big Muddy the dip is much steeper than at Glenrock, so that cross entries are driven out from the car track and other entries parallel to the main gangway, from which the rooms are driven in the direction of the strike. The coal is taken out of the rooms to the dip entry, then let down the dip to the cross entry, where it is hauled across to the main gangway by mules, and thence to the surface by cable.

PRODUCTION AND MARKET.

The coal production of Converse County in 1907 was 48,700 short tons. Big Muddy is very close to the western boundary of Converse County, but the mine is in this county and its production is included in the above figures.

Natrona County has no producing mines, except for local use, and its production is slight and comes from many mines and prospects. It is probable that in 1907 the total production of Converse and Natrona counties was not 1,000 tons in excess of the output of the

Glenrock and Big Muddy mines. This includes all the coal used by ranchmen and others, and much of this amount was not sold, but mined by consumers.

The market for the coal is found in towns along the Chicago and Northwestern Railway in this field, and to the east far into Nebraska. The coal has not been used by the railroad, because it decrepitates and is blown out of the smokestack by the heavy fire and draft of the locomotive. However, as similar coals are being used by other railroads, it seems probable that in time locomotives will be so modified as to burn coal from the Glenrock field. At present much more than half of the product goes to Nebraska, where it is used as steam and domestic fuel.

FUTURE OF THE FIELD.

The reasons why so little is being done with the coal in the Glenrock field seem to be (1) the scarcity of thick beds; (2) the high cost of mining due to thinness of bed, high price of labor and timber, poor roof, and presence of water; and (3) the inability to utilize the coal as locomotive fuel.

Nevertheless, this field, like all other areas containing coal, is one of growing importance, because of the growing population and the increasing demand for fuel. At present there is much coal in the field which can not be worked with profit, but it is probable that in the future more and more of this will be mined. The coal beds are generally lenticular, and they vary in quality from place to place, but careful prospecting would reveal many localities where even at the present time the coal could be worked with profit.

COAL FIELDS OF THE NORTHEAST SIDE OF THE BIGHORN BASIN, WYOMING, AND OF BRIDGER, MONTANA.

By CHESTER W. WASHBURN.

INTRODUCTION.

This report describes the coal fields of the northeast side of the Bighorn Basin, Wyoming, north of No Wood Creek, and also includes the connected Bridger field in southern Montana. The field work was done in the summer of 1907, under the general direction of C. A. Fisher. Max A. Pishel, E. F. Schramm, and Homer P. Little acted as field assistants. The territory was surveyed both topographically and geologically, land-survey lines being the basis of horizontal control. Land corners were located by pacing along alternate section lines, but where the geology or topography is intricate, or where the coal is valuable, every east-west section line was run. The outcrops of the workable coal beds were meandered, and at every available point they were measured.

Previous reconnaissance work on the coal of this area has been done by Eldridge,^a Fisher,^b and Darton.^c

LOCATION AND EXTENT.

The fields described in this paper are located mostly in the northeastern part of the Bighorn Basin, Wyoming, but extend northward across the valley of Clark Fork to the vicinity of Joliet, Mont. The length of the territory is 102 miles, the maximum width 30 miles, and the total area about 1,700 square miles. Bighorn River flows through the southeastern part.

TOPOGRAPHY.

The Bighorn Basin is essentially a region of broad, dissected plains, composed superficially of Tertiary deposits and Recent wash from the surrounding mountains. The controlling factor in the topography is Bighorn River, which enters the basin after passing through the Owl Creek Mountains in a canyon, traverses the east side of the

^a Eldridge, G. H., A geological reconnaissance in northwest Wyoming: Bull. U. S. Geol. Survey No. 119, 1894.

^b Fisher, C. A., Coal of the Bighorn Basin, in northwest Wyoming: Bull. U. S. Geol. Survey No. 225, 1904, pp. 345-362; Mineral resources of the Bighorn Basin, Wyoming: Bull. U. S. Geol. Survey No. 285, 1906, pp. 311-312; Geology and water resources of the Bighorn Basin, Wyoming: Prof. Paper U. S. Geol. Survey No. 53, 1906, pp. 46-56.

^c Darton N. H., Coals of Carbon County, Montana: Bull. U. S. Geol. Survey No. 316, 1907, pp. 174-193.

basin to the Pryor Mountains, through which it passes in another deep canyon, ultimately reaching Yellowstone River in central Montana. In the Bighorn Basin the river occupies a broad, alluvial valley, bordered by wide terraces which are extensively cultivated wherever irrigation is practicable.

In all the coal fields described in this paper, except the Silvertip field, the topography is gently rolling or hilly. The Laramie coal bed in the Basin field south of No Wood Creek outcrops in the valley of Sand Creek, which would furnish a convenient route for a spur of the Chicago, Burlington and Quincy Railroad. The same coal bed on the north side of No Wood Creek is readily accessible because it lies under an undissected plain. The workable part of the Fort Union coal bed in the Basin field lies beneath a gravel-covered terrace. The Laramie coal in T. 50 N., R. 93 W., outcrops in a sharp ravine and is not easy of access.

The coal district south of Lovell, in T. 55 N., R. 96 W., is a hilly area from which the coal will probably be removed only by wagon.

In the northern part of the Garland field the coal bed lies beneath a high plain, largely covered by coarse gravel, but in the southern half of T. 57 N. the coal outcrops near the top of a high, eastward-facing escarpment. In T. 56 N. the outcrop is again in the low country of gentle relief that characterizes the southern part of this field.

The Silvertip field is an anticline in which the coal encircles an open valley known as the Elk basin. On the east side of the field the coal outcrops in westward-facing cliffs. On the west side the coal outcrops generally in the second hogback ridge. Here, as well as at the north end of the field, the coal bed dips beneath a region of deeply cut valleys and high hills. The largest of these valleys, that of Silvertip Creek, furnishes a direct and feasible route for a railroad connecting with the Yellowstone Park Railroad below Belfry.

The outcrop of the coal bed of the Bridger field north of Clark Fork follows an eastward-facing escarpment of Eagle sandstone. In several places this escarpment is broken by the small valleys of eastward-flowing transverse streams, in which the coal is more readily accessible; yet there is no place on the outcrop of the coal bed north of Bridger that could not be reached by a short spur from one of the two branches of the Northern Pacific Railway. The coal bed south of Bridger, in T. 7 S., R. 23 E., outcrops in rolling hills in the northern part of the township and in high ridges in the southern part. The isolated area of workable coal on the south edge of T. 8 S., R. 24 E., is in a high, rugged cliff facing toward Jack Creek. The proposed Scribner-Fromberg branch of the Burlington Railroad would pass down Jack Creek, about 2 miles from the coal outcrop.

Horseback travel over the region is easy, and there are many roads over which wagons may be taken. Timber is limited to deciduous trees, growing along the alluvial plains of the rivers, and to a few

scraggy pines on some of the higher sandstone ridges. Elsewhere there is no vegetation except sagebrush, prickly pear, greasewood, grasses, and similar small plants. The nearest trees suitable for mine timber grow on Pryor Mountain, northeast of Bowler; on the Bear-tooth Mountains, 25 miles southwest of the Bridger field; and on the headwaters of No Wood Creek, 35 miles southeast of the Basin field.

GEOLOGY.

STRATIGRAPHY.

GENERAL SECTION.

The rocks exposed on the east side of the Bighorn Basin embrace strata of all ages from the Carboniferous to the lower Eocene, but only the Cretaceous and Tertiary formations need be considered, as they are the only ones containing coal. These formations are shown in the accompanying geologic section.

Stratigraphic column on the east side of the Bighorn Basin, Wyoming.^a

Series.	Group.	Formation.	Thickness (feet).	Characteristics.
Eocene (Tertiary).		Wasatch formation.	500	Bright-colored clays, with a few thin lenses of sandstone. Contains workable coal in the central part of the basin.
		Unconformity.		
		Fort Union formation.	1,000 to 2,000	Dark-colored shale and massive sandstone. Contains workable coal.
		Unconformity (?)		
Upper Cretaceous.	Montana.	Laramie (?) formation. ^b	150 to 700	Massive sandstone with subordinate shale. Contains workable coal.
		Bearpaw shale.	150	Dark marine shale.
		Judith River formation.	300 to 400	Variegated clays and soft sandstone.
		Claggett formation.	400 to 500	Massive fresh and brackish water sandstones and dark shale. Coal not workable.
		Eagle sandstone.	150 to 225	Massive fresh and brackish water sandstones, separated by carbonaceous shale. Contains workable coal.
		Colorado shale.	4,400	Dark shale with one or two conspicuous sandstones, not divisible in this field, though more than 1,500 feet of the lower part is known to be equivalent to the Benton shale.
		Unconformity.		
Lower Cretaceous (?).		Cloverly.	0 to 275	Bright-colored clays, with massive sandstones at the top and bottom. Coal not workable.

^a For the recognition of the formations in the field the writer is indebted to the guidance of C. A. Fisher. The subdivisions of the Montana group are correlated with similar subdivisions proposed by Stanton and Hatcher in the Judith River region of northern Montana (Stanton, T. W., and Hatcher, J. B., *Geology and paleontology of the Judith River beds*; Bull. U. S. Geol. Survey No. 257, 1906). This correlation also is made possible through the work of Fisher, who has traced the formations southward from the type locality into Wyoming (Econ. Geology, vol. 3, 1908, pp. 77-99).

^b The evidence is not sufficient to class this formation as undoubted Laramie, consequently the term is used throughout this report in a questionable sense.

DESCRIPTION OF FORMATIONS.

Cloverly formation.—At the base of the Cloverly formation in its typical development on Gypsum Creek, north of Lovell, Wyo., there is 40 to 50 feet of massive sandstone, locally containing shale partings and a thin coal bed. The coal is of little economic importance, though it has been mined at times for local use near Bell's ranch on No Wood Creek. There is no coal in the Cloverly at any place within the territory studied by the writer. Overlying the sandstone are 100 to 150 feet of bright variegated clays and soft sandstones, with concretions of limestone and chert. The top member of the formation is a massive gray sandstone about 70 feet thick, overlain by 15 feet of dark-purplish shale. In all other places examined none of the formation above the basal sandstone is certainly present, and in most places the entire formation is absent. This hiatus is due to an unconformity, separating the Cloverly formation from the overlying marine Colorado shale. The age of the Cloverly is believed to be Lower Cretaceous, probably equivalent to that of the Kootenai of northern Montana and Alberta.^a

Colorado shale.—The Colorado shale consists of over 4,000 feet of dark marine shale, with one or two conspicuous sandstones about 1,000 feet above the base. The upper part of the formation is probably synchronous though not lithologically identical with the Niobrara, and an indeterminate amount of the lower part of the formation is of Benton age. The Benton fauna ranges through more than 3,000 feet of the lower part of the formation. The Colorado contains some oil and probably valuable stores of gas. In its lower part occur thin beds of pure white bentonite.

Eagle sandstone.—The Eagle sandstone consists of two or three massive sandstones, 35 to 75 feet thick, separated by carbonaceous shale with three beds of coal. These are the workable beds of the Silvertip and the Bridger coal fields.

Claggett formation.—Overlying the Eagle is another partially marine formation, the Claggett, consisting of massive yellow and gray sandstones with subordinate dark shale. Beds of coal occur in the formation in most exposures, but they are thin and valueless.

Judith River formation.—The Judith River formation is like the Cloverly in its bright coloration. It consists of variegated green, white, purple, and red clays and soft white sandstone. Fossil wood and bones are abundant nearly everywhere in this formation.

Bearpaw shale.—The Bearpaw shale consists of dark, thin-bedded shale, in many places laminated, with rarely some thin beds of sandstone. The shale is thought to be marine, but no marine fossils have been found south of the Silvertip anticline on the Montana-Wyoming

^a Fisher, C. A., Southern extension of the Kootenai and Montana coal-bearing formations in northern Montana: *Econ. Geology*, vol. 3, 1908, pp. 77-99.

State line. At that place fossils of the Pierre fauna (marine) were collected from calcareous nodules in black shale.

Laramie formation.—The Laramie formation consists of 150 to 700 feet of massive sandstone with subordinate shale. The sandstones are thick, coarse grained, and conspicuous, and contain many large ferruginous concretions. Usually the massive sandstone at the top of the Laramie is white from leaching or other causes. In the Basin field the lower part of the formation contains 100 feet of varicolored soft shale—dark green, white, black, and other colors—in which there are three closely adjacent coal beds. The middle bed is workable. In the Garland field three or more coal beds occur between 300 and 400 feet above the base of the Laramie, above a series of massive sandstones and at the base of several hundred feet of dark shale.

Fort Union formation.—The contact between the Fort Union and the Laramie is probably unconformable, but the unconformity is not apparent in most places, and the formations are hard to separate in the field. Lithologically they are almost identical. The Fort Union consists principally of dark shale with thick lenticular masses of sandstone. The sandstone is especially abundant near the bottom of the formation, where some of the beds are in places more than 100 feet thick. West of Sheep Mountain there is over 1,200 feet of white conglomeratic sandstone at the base of the Fort Union, but this is exceptional. The lenticular sandstones in the formation contain many ferruginous concretions, which reach 40 feet or more in diameter. The shale contains smaller, hard, dense, ferruginous concretions, weathering yellow and brown. These are characteristic of the formation. Coal occurs locally in all parts of the Fort Union formation. The coal beds mined southwest of Basin, near Manderson, are about 700 feet above its base.

Wasatch formation.—The Wasatch formation is a series of variegated red and pink banded shales or clays, containing subordinate, irregular, nonpersistent beds of soft white sandstone. It rests in places unconformably on the upturned edges of the underlying formations; in other places the unconformity is not conspicuous. The Wasatch does not contain coal.

STRUCTURE.

In general, the structure of the coal-bearing rocks is that of a simple westward or southwestward dipping monocline, forming part of the east limb of the Bighorn Basin syncline. The angle of dip is low (2° to 20° SW.) at all places where the coal is of workable thickness. West of Sheep Mountain the Laramie coal beds are nearly vertical, but they have no economic value. In the central part of the basin the coal beds are doubtless flat, but they are covered by several thousand feet of barren rock.

Folds.—A small anticline in the Basin coal field results in northeasterly dips for a short distance in T. 50 N., R. 92 W. The coal bed follows a devious S-shaped course around the anticline and the adjoining syncline.

The only other fold affecting workable coal beds is the Silvertip anticline. At Silvertip the coal of the Eagle sandstone is exposed in a broad, domelike, unsymmetrical anticline, with dips of 11° to 20° SW. on the west limb and of 20° to 45° NE. on the east limb.

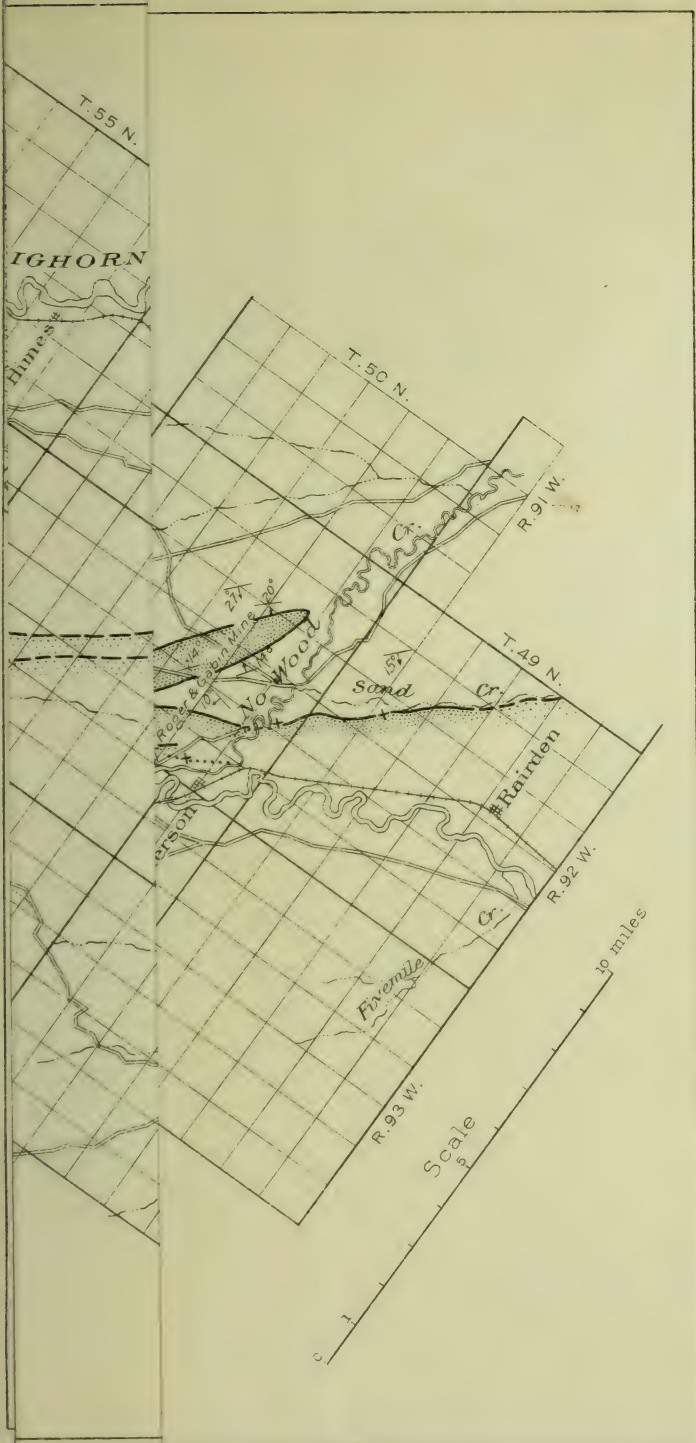
As shown by the geologic map (Pl. X), the nonworkable parts of the coal beds are involved in a number of small anticlinal and synclinal folds near Garland and Lovell, Wyo.

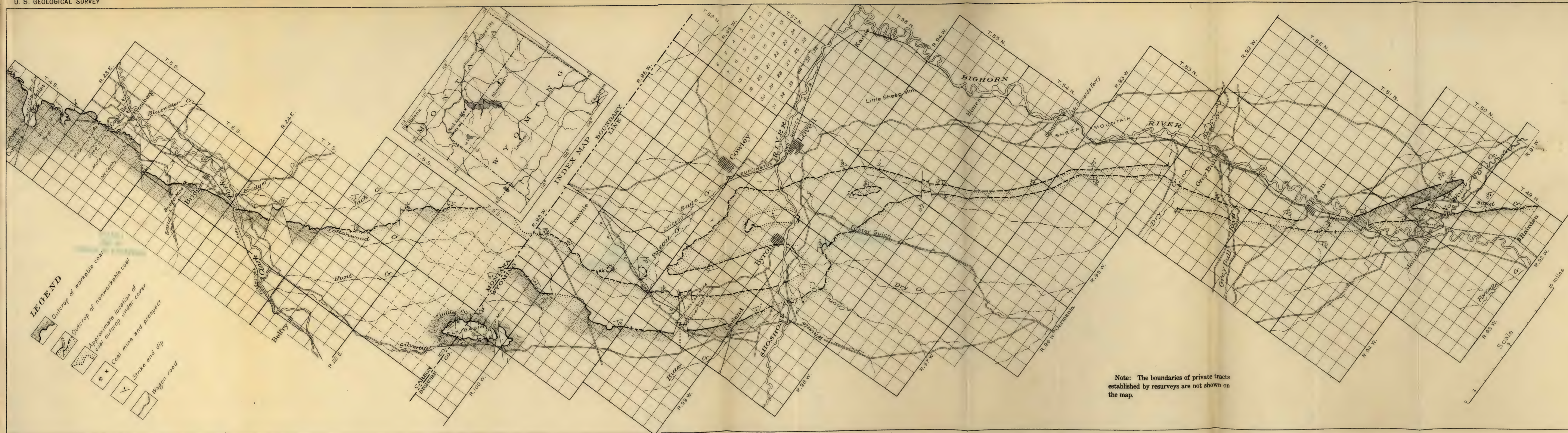
Faults.—Small dip faults, trending nearly at right angles to the strike, occur in all parts of the field. They are especially common on the anticlines. As a rule, these faults will not interfere with mining, except in the Silvertip anticline, on the east side of which some of them are so closely spaced as to prevent the development of side workings more than 2,000 feet from the main entries. Along a large isolated fault 4 miles north of Bridger, Mont., the outcrop of the Bridger coal bed is offset nearly 2 miles. A smaller isolated fault encountered in the Rogers & Gapin mine, near Manderson, Wyo., probably offsets the outcrop of the coal bed to the Converse prospect, on the bank of No Wood Creek. Depressed fault blocks, with their longer axis across the strike and widening in the direction of the dip, are characteristic features of the structure. The Hopkins and Sarver coal mines are located near the southern and northern limits, respectively, of one of these depressed fault blocks. The north boundary fault of this block offsets the outcrop of the coal bed over three-fourths of a mile; the south boundary offsets the outcrop over one-fourth of a mile. There is a similar depressed fault block 6 miles south of Bridger, Mont., in which the Bridger coal bed is offset three-fourths of a mile to the east. (See map, Pl. X.)

DISTRIBUTION OF COAL.

Coal occurs in the Cloverly, Eagle, Claggett, Laramie, and Fort Union formations. The coal of the Cloverly is not workable within the borders of the area mapped, but Fisher reports that a coal bed from which coal has been mined for domestic use on neighboring farms occurs near the base of this formation in the vicinity of Bonanza, about 25 miles southeast of Basin, Wyo.

The Claggett formation contains several thin beds, none of which is of economic importance. On Dry Creek, west of Grey Bull, Wyo. (see p. 172), an opening has been made on a Claggett coal bed, which is not workable. The best exposure of Claggett coal is on the south bank of Shoshone River, near Byron (see p. 181), where there is 21 inches of coal.





The coal of the Eagle sandstone is workable only in the northern part of the area, in the Clark Fork valley, Montana, and in the Silvertip coal field, near the State line. The formation contains three coal beds, only one of which is workable at any one point in the Clark Fork valley, but two of which are workable at many places in the Silvertip field. South of the Silvertip field the coal beds deteriorate and are replaced by black carbonaceous shale which contains thin partings of coal less than 1 foot thick. These partings disappear a short distance south of Shoshone River. Farther south the shale is less carbonaceous, and at the crossing of Dry Creek it is a yellow sandy shale, with no suggestion of coal or carbonaceous matter such as characterizes it farther north. The beds at this horizon maintain this character in the southern part of the area studied in 1907, but beyond that area, in the southeastern part of the Bighorn Basin, the formation again contains workable coal.

Coal of the Laramie formation is known to occur at the south end of the area, on Sand Creek, a tributary of No Wood Creek. From this point the coal beds—three in number—at the base of the Laramie formation may be traced northwestward across Bighorn River to a point southwest of Basin, where they disappear beneath the surface wash. Between this point and the neighborhood of Garland, 45 miles northwest of Basin, workable coal beds have not been discovered in the Laramie, although prospecting has been thoroughly done. Near Garland there are two or more workable beds which have been traced northward about 10 miles to a high terrace, on which the outcrop of the coal is covered by gravel. Where the bed reappears on the north side of this terrace the coal is not workable, and there is no point in Montana within the field studied by the writer where the Laramie coal reaches minable thickness.

Coal occurs in the Fort Union formation at several horizons, but the coal beds are not persistent. A coal in this formation is mined on the east side of Bighorn River, 10 miles southeast of Basin, Wyo. North of this point the coal is probably not workable, except in a small district southwest of Lovell, where there is about 2 feet of coal, and possibly at one locality west of the Silvertip field, where about 3 feet of coal was found in this formation. Near the latter locality exposures of the same bed showed less than 18 inches of coal.

THE COAL.

Although the coal-bearing formations extend continuously from one end of the area examined to the other, nevertheless the area is divisible into four distinct fields, which contain all the coal of economic importance. These fields are separated by larger areas within which coal is either absent or else too thin to be mined. The fields are designated as follows: (1) The Basin coal field, south of Basin, Wyo.,

with which for convenience is included a small coal district south of Lovell; (2) the Garland coal field, north and east of Garland, Wyo.; (3) the Silvertip coal field, at the head of Silvertip Creek, 20 miles south of Bridger, Mont., and (4) the Bridger coal field, extending from the vicinity of Bridger northward beyond Joliet, Mont.

BASIN COAL FIELD.

The Basin field, at the south end of the territory mapped, consists of a small area of about 15 square miles, lying on both sides of No Wood Creek, principally east of Bighorn River.

Coal in Claggett formation.—Coal is present in the Claggett formation at a number of places in the Basin field, but has no economic value. The following section indicates the nature of the coal beds:

Section of coal beds on Dry Creek, 2 miles west of Grey Bull, Wyo.

	Ft.	in.
Coal.....	4	
Bone.....	6	
Coal.....	4½	
Shale, lignitic.....	1	6
Shale, carbonaceous, and sandstone.....	18	
Sandstone, soft.....	1	6
Coal, bony.....	11	

From this locality the coal has been traced south-southeastward across Grey Bull River, 2½ miles above the town of Grey Bull. It is exposed near the railroad, on the bank of a small creek 1 mile south of Basin. Here only 14 inches of coal is present, and south of this point the coal disappears.

Coal in Laramie formation.—The Laramie coal beds are well developed in the Basin field. On the west bank of Sand Creek, the southern tributary of No Wood Creek, they outcrop for a distance of 4 miles, occurring in a series of variegated greenish-white and dark carbonaceous shales. The shales resemble those of the Judith River formation, both in appearance and in being very soft, so that valleys have been eroded in them. The coal is typically shown on the south bank of No Wood Creek, 1½ miles southwest of the Jordan mill, where the following section was measured:

Section of coal bed and associated rocks on the south bank of No Wood Creek, Wyoming.

	Ft.	in.
Sandstone, gray.....	30	
Sandstone, pure white (probably base of Fort Union).....	12	
Shale, dark, carbonaceous (Laramie?).....	74	
Sandstone and sandy shale.....	5	
Coal.....	4½	
Clay.....	1	
Coal with bony streaks, poor.....	1	11
Total coal.....	2	3½

About 225 yards northwest of this opening is a prospect with 30 inches of bright, clean coal, containing 2 to 4 inches of bony coal which is dull black and includes small, lenticular clay concretions.

There are three coal beds present in these shales at most localities. The lower bed is in all exposures the best of the three, and usually it is the only one that is workable. A section of this bed in the Cox prospect on Sand Creek is given below.

Section of coal bed on Sand Creek, 2½ miles south of Jordan mill, in sec. 10, T. 49 N., R. 92 W.

Sandstone?	Ft. in.
Coal.....	11
Bone.....	1
Coal.....	4
Clay.....	5
Coal.....	4
Clay.....	2
Coal.....	1 8
Clay.....	½
Coal.....	8
Shale, carbonaceous.	
Total coal.....	3 11

Farther south the bed deteriorates, and in the SW. ¼ NE. ¼ sec. 14, T. 49 N., R. 92 W., the lower bed contains only 1 foot 4 inches of coal. It is not workable south of this point. On the north bank of No Wood Creek the middle bed is only 23 inches thick and is not workable. As shown by the map, the outcrop of the Laramie coal follows a devious, S-shaped course through T. 50 N., R. 92 W., where it is involved in an anticlinal and a synclinal fold. The exposures are poor in this township, and it is uncertain whether or not the coal reaches workable thickness.

In section 12 of the next township west the coal is well exposed in an old prospect, where the following section was obtained:

Section of coal bed 5 miles southeast of Basin, in sec. 12, T. 50 N., R. 93 W.

	Ft. in.
Coal.....	8
Shale.....	15
Coal.....	1 3
Coal, bony.....	2
Shale, carbonaceous.	

North of this point the coal is not workable. On the south bank of No Wood Creek, in sec. 33, T. 50 N., R. 92 W., the following section was obtained:

Section of coal beds 1 mile south-southwest of Jordan mill, in sec. 33, T. 50 N., R. 92 W.

	Ft.	in.
Sandstone and sandy shale.....	10	
Coal.....		9
Shale.....		3
Coal, dirty.....		1
Shale, carbonaceous, and unexposed rock.....	15	
Sandstone, concretionary.....	8	
Shale, carbonaceous, and coaly.....		2
Coal, bony.....		3
Coal.....		11
Shale, sandy.....		1
Coal.....	1	1

Coal beds occur also at higher horizons, believed to be in the Laramie formation. A section of one of these upper beds which outcrops in the SW. $\frac{1}{4}$ sec. 25, T. 52 N., R. 94 W., is given below.

Section of Laramie (?) coal bed 4 miles southwest of Grey Bull, in sec. 25, T. 52 N., R. 94 W.

	Ft.	in.
Sandstone, yellow, heavy.....		
Shale, lignitic.....	4	
Sandstone, yellowish.....	4	
Coal.....	1	3
Shale.....	6	
Coal.....		5
Sandstone, heavy, whitish.....	2	1
Coal.....		8
Total coal.....	2	4

In sec. 6, T. 53 N., R. 94 W., the coal is only 6 inches thick. In sec. 8 it is 18 inches thick. A good idea of the character of the upper coal beds may be obtained from the following section, made 250 feet southwest of the north quarter corner of sec. 16, T. 53 N., R. 94 W.:

Section of coal beds $8\frac{1}{2}$ miles northwest of Grey Bull, in sec. 16, T. 53 N., R. 94 W.

	Ft.	in.
Sandstone (probably base of Fort Union).....	12	
Shale.....	2	
Coal.....		6
Shale.....	20	
Sandstone.....	10	
Coal.....	1	6
Concealed.....	30	
Coal.....		1
Shale.....	18	
Sandstone.....	10	
Shale.....	10	
Coal, bony, and shale.....		3
Shale, carbonaceous.....	10	
Coal.....	1	3
Total coal.....	7	3

Coal in the Fort Union formation.—The thickest coal beds of the Basin field are found in the Fort Union formation. At the Rogers & Gapin coal mine, 7 miles south-southeast of Basin, there is over 5 feet of coal in one of these beds, separated by many thin partings of shale, which are hard to remove in mining and which therefore make the commercial product very dirty. The coal is too friable to be well adapted to washing. The following section was made at the working face of the mine:

Section of coal bed in Rogers & Gapin mine.

Shale.	Ft.	in.
Coal.....	1	7
Shale.....		1 $\frac{1}{4}$
Coal.....		7 $\frac{1}{2}$
Shale.....		$\frac{1}{2}$
Coal.....		1 $\frac{1}{2}$
Shale.....	2	
Coal.....		7 $\frac{1}{2}$
Shale.....		5
Coal.....		5
Shale.....		1
Coal.....		5 $\frac{1}{2}$
Shale.....		1
Coal.....		6 $\frac{1}{2}$
Bone.....		1 $\frac{1}{4}$
Coal; said to be best part of bed.....	1	4
Shale.		

Total coal.....	5	8 $\frac{1}{2}$
-----------------	---	-----------------

At another place in the same mine Fisher^a made the following section in 1905:

Section of coal bed in Rogers & Gapin mine.

	Ft.	in.
Coal.....	1	1
Shale, impure, coaly.....		1
Coal.....		8
Shale, black.....		2
Coal.....		7
Clay, dark gray.....		6
Coal.....		5
Shale, coaly.....		2
Coal.....		11
Clay, dark gray.....		2
Coal.....	1	3
Total coal.....	4	11

^a Geology and water resources of the Bighorn Basin: Prof. Paper U. S. Geol. Survey No. 53, 1907, p. 54.

The coal bed is thinly covered and shows slight evidence of weathering in the deposition of sulphur and salts in some of the joints. The coal slacks rapidly and can be kept in stock only a month or two. The sulphur and ash are both high, the sulphur exceeding that of any of the other coals of the Bighorn Basin. (See analysis, p. 198.) The coal is finely banded, bright layers with waxy luster predominating over dull layers. The parting along the bedding planes is well developed, causing the coal to break into thin plates. The cross breaks are irregular, with a tendency to conchoidal fracture in the hard, bright layers.

The mine was opened more than twenty years ago. It has been worked almost continuously since 1900, with an average production, according to Fisher,^a of about 400 tons per year. In 1907 the output was about 1,000 tons, but this will probably increase, as the product is used entirely by the town of Basin, which has been growing rapidly in population since the construction of the railroad. The coal is sold for about \$2 per ton at the mine. It is hauled to Basin in wagons.

On the east bank of No Wood Creek, one-half mile northeast of Manderson, is an opening known as the Converse prospect, at which the following section was made:

Section of coal bed at the Converse prospect, near Manderson.

Shale.	Ft.	in.
Coal, dirty.....	1	2
Shale.....		2
Coal.....		6
Shale.....		$\frac{1}{2}$
Coal.....		4
Shale.....		4
Coal.....		6
Shale.....		8
Coal.....		8
Shale.....		10
Coal.....		8
Shale.....		1
Coal.....		10
Shale.....		4
Coal.....	1	4
Clay.		
Total coal.....		6

This is thought to be the same coal bed as that exposed in the Rogers & Gapin mine; but if it is, there must be a fault between the two openings, producing an offset of over a quarter of a mile. The miners report that in the Rogers & Gapin mine they encountered a fault which cut off the coal bed at the end of the abandoned workings. This fault could not be examined in 1907, on account of a fire in the

^a Loc. cit.

mine. North of this mine the coal is workable for only a short distance, deteriorating rapidly to a bed of brown, lignitic shale, which contains a few coal partings. At the Converse prospect the coal bed disappears under the alluvium of the No Wood Valley, reappearing in a railroad cut 1 mile south of Manderson. At the latter point the coal is not workable, its total thickness being only 15 inches.

Southwest of Basin several openings have been made on the Rogers & Gapin coal bed. Coal has been mined from these openings for local use, but on account of the thinness of the bed it is probable that shipping mines can not be developed in this locality. Measurements made in the SW. $\frac{1}{4}$ sec. 33, T. 51 N., R. 93 W., show from 14 to 18 inches of clean coal occurring in bony coal and carbonaceous shale. In the NW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 29, T. 51 N., R. 93 W., the coal is possibly workable, as may be seen by an inspection of the following section:

Section of coal bed in an old prospect $1\frac{3}{4}$ miles southwest of Basin, in sec. 29, T. 51 N., R. 93 W.

Shale.	Ft. in.
Coal.....	1 7
Shale.....	6
Coal.....	6
Total coal.....	2 1

When Fisher visited this neighborhood in 1905 one of the mines was in operation, but it was abandoned soon afterward on account of the thinning out of the coal bed. Fisher^a writes of this mine:

There is another mine in this district, located about 1 mile southwest of Basin, owned by G. N. Mecklen. The bed is $2\frac{1}{2}$ feet thick, with a 6-inch shaly parting near the base. The coal is contained in sandy beds, which here dip to the south at such a steep angle that the limit of economic mining will soon be reached. This mine produces about 600 tons a year, which is consumed by the residents of Basin and the Bighorn River Valley. The mine is poorly improved and the bed is too thin to warrant any considerable development, as is shown by the following section:

Section of coal bed at Mecklen mine, near Basin, Wyo.

	Ft. in.
Coal.....	2
Slate, dark-gray.....	6
Coal.....	6
Total coal.....	2 6

North of this point the coal is not known to be workable at any place. It is exposed on the wagon road between Basin and Germania, 2 miles west of Basin, also in the SW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 10, T. 52 N., R. 94 W.

Coal occurs at higher horizons in the Fort Union formation, but these are irregular and nonpersistent. So far as known, none of the higher beds are of workable thickness. A 15-inch bed outcrops on

^aLoc. cit.

the bluff one-half mile southwest of Manderson station, in the NE. $\frac{1}{4}$ sec. 36, T. 50 N., R. 93 W., and there are two similar beds outcropping on the bluffs of Elk Creek, near the middle of sec. 15, T. 50 N., R. 93 W.

Lovell coal district.—South and southwest of Lovell, Wyo., there are two or more thin coal beds, probably in the Laramie formation, but possibly at the base of the Fort Union. It seems likely that the beds occur at nearly the same horizon as those at the Sarver and Hopkins mines, north of Garland. The lower bed is the poorer, being only 6 inches thick in some places, and at no place 2 feet thick. The upper bed is of workable thickness in the SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 11, T. 55 N., R. 96 W., as shown by the following section:

Section of coal bed in sec. 11, T. 55 N., R. 96 W.

	Ft.	in.
Coal.....	6	
Shale.....	1	
Coal.....	1	6
Shale.....	4	
Coal.....	1	6
Total coal.....	3	6

The above measurement was made on the north side of a small, isolated coal basin or syncline. (See Pl. X.)

The same bed is exposed in a prospect 7 miles south of Lovell, in the NW. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 21, T. 55 N., R. 96 W. The bed here attains its maximum thickness, 2 feet 10 inches, and is opened by an entry 75 feet long, from which coal is hauled to Lovell by wagon. A section of the bed is given below:

Section of coal bed in sec. 21, T. 55 N., R. 96 W.

	Ft.	in.
Sandstone.....		
Coal.....	5	
Shale.....	1	
Coal.....	1	2
Shale.....	7	
Coal.....	7	
Shale.....	1	
Coal.....	8	
Total coal.....	2	10

At other places in the same township the beds are too thin and dirty to be mined, as shown by the following sections:

Sections of Laramie (?) coal beds in T. 55 N., R. 96 W.

SW. $\frac{1}{4}$ SW. $\frac{1}{4}$ SEC. 16.		Ft. in.
Shale.....	2	
Coal.....	5	
Shale.....	1	
Coal.....	1	
Shale.....	7	
Coal.....	5	
Total coal.....	1	10

NW. $\frac{1}{4}$ NE. $\frac{1}{4}$ SEC. 18.		Ft. in.
Sandstone.....		
Shale.....	2	
Coal.....	5	
Shale.....	1	
Coal.....	1	
Shale.....	5	
Coal.....	2	
Shale.....	1	
Coal.....	2	
Shale.....	2	6
Coal.....	2	
Shale.....	1	
Coal.....	4	
Shale.....	2	
Coal.....	4	
Shale.....		
Total coal.....	1	8

NW. $\frac{1}{4}$ NW. $\frac{1}{4}$ SEC. 18.		Ft. in.
Sandstone.....		
Shale.....	3	
Coal.....	6	
Shale.....	8	
Coal.....	5	
Shale.....	6	
Coal.....	2	
Total coal.....	1	1

NW. $\frac{1}{4}$ SE. $\frac{1}{4}$ SEC. 22.		Ft. in.
Sandstone, shaly.....		
Coal.....	10	
Shale.....	9	
Coal.....	6	
Shale.....	2	
Coal.....	6	
Total coal.....	1	10

NW. $\frac{1}{4}$ SW. $\frac{1}{4}$ SEC. 23.		Ft. in.
Shale, sandy.....		
Coal.....	4	
Shale.....	1	
Coal, somewhat dirty.....	9	
Shale.....		
Total coal.....	1	1

Section of Laramie (?) coal bed in SW. $\frac{1}{4}$ sec. 12, T. 55 N., R. 97 W.

SW. $\frac{1}{4}$ sec. 12, T. 55 N., R. 97 W.		Ft. in.
Sandstone.....		
Shale.....	4	
Coal.....	4	
Shale.....	8	
Coal.....	6	
Shale.....		
Total coal.....		10

GARLAND COAL FIELD.

The Garland coal field extends from Shoshone River near the town of Garland, Wyo., northward to the Montana line. Coals are present in the Claggett, Eagle, Laramie, and Fort Union formations, but only those in the Laramie are workable.

Coal in Eagle sandstone.—Coal has been mined by farmers for their own use from a thin bed 2 miles north of Byron, Wyo., in sec. 15, T. 56 N., R. 97 W. This bed is in the Eagle sandstone. Its section is as follows:

Section of coal bed in an old mine 2 miles north of Byron, in sec. 15, T. 56 N., R. 97 W.

	Ft. in.
Coal.....	6
Clay.....	6
Coal.....	1 3
Total coal.....	1 9

The coal outcrops in the northwest end of a small anticline which trends southeastward from this point, running beneath the alluvium of the Shoshone River valley and reappearing in the bluffs on the south side. The same bed is exposed in the cliffs on the south side of Sage Creek, 1 mile southwest of Cowley station. The coal has been traced westward along these bluffs for about 8 miles to sec. 3, T. 56 N., R. 98 W., where it bends sharply across the axis of a syncline and then runs southeastward along the east side of the Garland anticline. On the west side of the Garland anticline the coal bed has been traced northwestward from Shoshone River to the Bridger field in Montana. In the bluffs on the north side of Shoshone River, in the NE. $\frac{1}{4}$ sec. 6, T. 55 N., R. 97 W., Eagle coal is exposed in the following section:

Section of Eagle coal bed 4 miles east of Garland, in sec. 6, T. 55 N., R. 97 W.

	Ft. in.
Sandstone, massive, yellow, Eagle.....	35
Clay.....	2
Coal.....	5
Coal, bony.....	10
Clay.....	6
Coal.....	5
Shale, carbonaceous.....	5
Clay.....	2
Shale, carbonaceous.....	3
Total coal.....	1 8

Eight miles northwest of this point there is a prospect in the NW. $\frac{1}{4}$ sec. 4, T. 56 N., R. 98 W., about a quarter of a mile east of the Cody branch of the Burlington Railroad. The coal here is about 20 inches thick. The Eagle coal bed is not believed to exceed this thickness in any part of the Garland coal field. On Polecat Butte, 4 miles southwest of Frannie, Wyo., this coal horizon is represented by black carbonaceous shale containing a few worthless streaks of coal. Such is its character from this point northward beyond the State line.

Coal in the Claggett formation.—The Claggett formation contains thin beds of coal at many places in the Garland field. These beds are not workable at any of the exposures examined by the writer, the greatest thickness being only 1 foot 9 inches. This exposure is in the SW. $\frac{1}{4}$ sec. 5, T. 55 N., R. 97 W., 3 miles below the Garland wagon bridge, on the south bank of Shoshone River. The section here is as follows:

Section of Claggett coal beds on the south bank of Shoshone River, in sec. 5, T. 55 N., R. 97 W.

	Ft.	in.
Clay, white (bentonite?).....	6	
Coal.....	1	
Shale, carbonaceous, and bony coal.....	1	6
Coal.....		9
Shale and sandstone.....	59	
Coal.....		5
Shale, hard.....		3
Coal.....		3
Shale, hard.....		4
Coal.....	1	1
Shale, carbonaceous.....	1	3
Coal.....		6
Shale, carbonaceous.....		8

Coal in the Laramie and Fort Union formations.—The minable coal of the Garland field occurs in the Laramie and Fort Union formations, near the dividing line between the two. As the Laramie can not be clearly distinguished from the Fort Union in this field, it is impossible to tell whether some of the beds are Fort Union or Laramie, and consequently no attempt will be made to differentiate them.

Three miles north-northwest of Garland are two mines which were worked a few years ago to supply the local coal market. In one of these, known as the Sarver mine, the coal has the following thickness:

Section of coal bed in the Sarver mine, 3 miles north of Garland.

	Ft.	in.
Shale, sandy.....		
Coal.....	2	
Shale.....	2	2
Coal.....	1	
Shale.....		4
Coal.....	1	
Total coal.....	4	

About 200 feet north of the Sarver mine there is an opening on an underlying bed which shows 4 feet of clean coal beneath a good sandstone roof. This mine and the Hopkins mine, half a mile farther north, are located on opposite sides of a depressed fault block. On the south side of this block the coal beds are offset more than one-fourth of a mile; on the north side they are offset more than three-fourths of a mile.

Close to the northeast corner of sec. 13, T. 56 N., R. 99 W., 32 inches of coal is exposed in an old slope. Only one bed appears to be present at this point. One mile farther northwest, in the NW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 1, the same bed is 3 feet thick. The bed at this point contains a $\frac{3}{4}$ -inch shale parting 4 inches below the top. In places the upper 4 inches of the bed is bony. There is a small mine on this bed in the SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 1, T. 56 N., R. 99 W. At this mine there is 30 to 40 inches of coal, thickening from the entrance

inward. The bed is clean except for two 6-inch clay-ironstone concretions observed at one place. The mine consists of a slope 100 feet in length with one 15-foot room turned southward at a distance of 80 feet from the entrance. The roof of the slope is sandstone, which stands without timber. The bed here dips 7° S. 65° W.

At the entrance to an old coal mine near the head of Polecat Creek, in sec. 24, T. 57 N., R. 99 W., the coal bed has the following section:

Section of coal bed at the head of Polecat Creek, in sec. 24, T. 57 N., R. 99 W.

Shale.	Ft. in.
Coal.....	3
Bone.....	6
Coal.....	1 2
Shale.	
Total coal.....	1 5

Such a bed would not be worked, but it is reported that the coal is about 30 inches thick farther in the mine. This report could not be verified because the workings had caved in and could not be examined. The coal at this point is in a gentle syncline. Where the bed reaches the top of a bluff on the northeast side of this syncline it is concealed by terrace gravel, beneath which it runs north-northwestward to the Montana line. The gravel is thin, and prospecting could be carried on by sinking small shafts or drill holes through it. The gravel is cut through by a small creek which exposes the coal in the W. $\frac{1}{2}$ sec. 1, T. 57 N., R. 99 W. too imperfectly, however, to make it possible to measure the thickness of the bed. There are two similar exposures, probably of the same bed, in the SE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 35 and the SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 25, T. 58 N., R. 99 W. The coal is possibly workable at both these places. At the latter exposure the following section was made:

Section of coal bed in sec. 25, T. 58 N., R. 99 W.

Shale.	Ft. in.
Coal.....	6
Shale.....	1
Coal.....	9
Shale.....	$\frac{1}{2}$
Coal.....	4
Shale.....	8
Coal.....	1 5
Total coal.....	3

North of the State line, in Montana, the Laramie-Fort Union coals are less than 2 feet thick at all points examined. It is reported that a bed of workable thickness occurs on the head of Cottonwood Creek, but it could not be found. Three coal beds about 18 inches thick were found on the west side of Little Cottonwood Creek, and there are innumerable smaller beds.

SILVERTIP COAL FIELD.

On the State line between Montana and Wyoming is an anticline which exposes the Eagle coal horizon. This fold may be known as the Silvertip anticline, from the name of the principal mine at that place, and the same name will be used in this report for the coal field. The field lies about 12 miles west of the line of the Chicago, Burlington and Quincy Railroad. It is about 20 miles northwest of Garland, Wyo., which is situated on the Cody branch of the Burlington Railroad, 21 miles south of Bridger, Mont., at the end of a branch of the Northern Pacific Railway; and 12 miles southwest of Belfry, Mont., on the Yellowstone Park Railroad, which connects at Bridger with the Northern Pacific. The coal is most accessible from Belfry, as the valley of Silvertip Creek would furnish a practicable route for a railroad between Silvertip and that town.

The Silvertip coal field is a broad ellipse about 8 miles long and 4 miles wide. On the west side of this ellipse the dips are southwestward at angles of 15° to 20° . On the east side the dips are slightly steeper, ranging from 22° to 45° NE. The continuity of the coal bed is broken by a great many normal faults which trend northeast and southwest across the axis of the anticline. These faults will probably interfere seriously with the mining of the coal on the east side of the anticline, but on the west side they are less numerous and will give little trouble. The throw of the faults ranges from 10 to 250 feet.

In the greater part of the Silvertip field, lying north of the State line, there are two workable coal beds, but most of the part of the field lying in Wyoming contains only one workable bed, though in places two beds may be found to be thick enough to mine.

Three coal beds are recognizable in the Silvertip field. These probably correspond to the three beds near Bridger and Fromberg, Mont. The lower bed is not workable at any place in this field. The workability of the two upper beds depends largely on the amount and strength of the material separating them. In most places this material is so thick that both coal beds can not be mined together, and in some places it is not thick enough nor strong enough to make it possible to mine the two beds separately. On the west side of the field the parting consists of only 2 to 8 feet of sandy shale, but on the east side it consists of 4 to 10 feet of sandy shale and sandstone, which is usually sufficient to permit both beds to be mined separately. Typical sections of the three beds as exposed on the west side of the field are shown on the following page.

*Sections of Eagle coal beds in SE. $\frac{1}{4}$ sec. 25, T. 58 N., R. 100 W.*OUTCROP 500 FEET SOUTH OF ENTRANCE
TO SILVERTIP MINE.

Upper bed:

Shale.	Ft.	in.
Coal, poor.....	6	
Coal, good.....	1	4
Bone.....	2	
Coal.....	1	10
Bone.....	2	
Coal, good.....	1	6
Sandstone, shaly.....	3	9
Total coal.....	4	8

Middle bed:

Coal, good.....	9	
Shale, black, bituminous	9	
Coal, very good.....	1	1
Shale.....	3	8
Total coal.....	1	10

Lower bed:

Coal.....	7	
Bone.....	2	$\frac{1}{2}$
Coal, bony.....	3	
Bone.....	2	5
Coal.....	6	
Shale.....	6	
Total coal.....	1	1

OUTCROP 600 FEET SOUTH OF ENTRANCE
TO SILVERTIP MINE.

Middle bed:

	Ft.	in.
Coal.....	9	
Shale.....	1	
Coal.....	1	1
Shale.....	4	5
Total coal.....	1	10

Lower bed:

Coal.....	7	
Bone.....	3	
Coal.....	3	
Shale.....	4	
Coal.....	1	
Shale, black, carbona- ceous.....	2	8
Coal.....		6
Sandstone and shale.....	55	
Total coal.....	1	5

Other sections of coal in the Silvertip coal field are as follows:

*Sections of coal beds in T. 58 N., R. 99 W.*NE. $\frac{1}{4}$ NW. $\frac{1}{4}$ SEC. 31.

Shale.	Ft.	in.
Coal, dirty.....	6	
Coal.....	6	
Bone.....	1	
Coal.....	4	
Bone.....	3	
Coal.....	1	7
Bone.....	2	
Coal.....	3	
Total coal.....	3	2

NW. $\frac{1}{4}$ NE. $\frac{1}{4}$ SEC. 30.

Upper bed:

Sandstone.		
Shale.	Ft.	in.
Coal.....	4	6
Shale.....	7	
Coal.....	1	
Shale.....	1	
Sandstone.....	4	
Total coal.....	5	6

Sections of coal beds in T. 58 N., R. 99 W.—Continued.

NW. $\frac{1}{4}$ NE. $\frac{1}{4}$ SEC. 30.		SE. $\frac{1}{4}$ NE. $\frac{1}{4}$ SEC. 30.	
	Ft. in.		Ft. in.
Middle bed:		Shale and strong thin-bedded sandstone.....	10
Coal.....	6	Sandy shale.....	5
Shale.....	3	Coal, with two 1-inch partings of bony coal containing thin concretions about 1 inch across.....	2 10
Coal.....	6	Shale, sandy.....	6
Shale, with some bituminous matter.		Coal.....	6
Total coal.....	1	Shale, carbonaceous.....	3
		Shale, sandy.....	10
Lower bed:		Coal.....	1
Shale.....	1 6	Shale, carbonaceous.....	4
Coal.....	2	Coal and carbonaceous shale in thin layers, not minable or valuable for any purpose; including a 12-inch, 8-inch, and 6-inch bed....	5
Total coal.....	2	Coal.....	1 5
NE $\frac{1}{4}$ NW. $\frac{1}{4}$ SEC. 19.		Sandstone, coarse, white, thin-bedded.....	4
Upper bed:		Coal.....	8
Sandstone.	Ft. in.	Sandstone, tawny.....	5
Coal.....	4		
Shale.....	4		
Coal.....	1		
Shale.....	10 (?)		
Sandstone.....	5		
Shale.....	3		
Total coal.....	5		
Middle bed:			
Coal.....	3		
Shale.....	1 6		
Coal.....	2		
Total coal.....	5		

In the northern part of the field the coal beds are most excellent, as shown by the following sections:

Section of coal beds in sec. 23, T. 58 N., R. 100 W. (Wyoming.)

Upper bed: ^a		Middle bed:	
	Ft. in.		Ft. in.
Shale.		Coal.....	3
Coal.....	3	Shale.....	4
Shale and bony coal....	5	Coal.....	11
Coal.....	3	Shale and bony coal....	2 4
Shale, carbonaceous.....	1 6	Coal.....	2 10
Shale, sandy.....	10	Shale, carbonaceous.....	4
Sandstone.....	2	Total coal.....	4
Shale, carbonaceous.....	2		
Total coal.....	3 3	Lower bed:	
		Coal.....	8

^aThe upper bed is exposed in a prospect on the east line of sec. 23, 1,600 feet south of the State line.

Section of coal beds in NE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 35, T. 9 S., R. 23 E. (Montana).

Upper bed:	Ft. in.	Middle bed:	Ft. in.
Coal.....	9	Coal.....	3 11
Clay.....	8	Lower bed:	
Coal.....	4	Bands of shale and coal; not	
Total coal.....	4 9	workable. Thickest coal,	
		8 inches.	

In the southern part of the field the coal beds are thinner, as shown by the following section, which is typical of that part of the field:

Section of coal beds in sec. 5, T. 57 N., R. 99 W. (Wyoming).

	Ft. in.
Sandstone, tawny, strong.....	5
Shale, sandy, carbonaceous.....	10
Coal.....	6
Shale, carbonaceous.....	3
Coal, bony, with carbonaceous shale partings.....	2
Shale, carbonaceous.....	1
Coal.....	1 3
Coal, bony in places; mostly carbonaceous shale; other	
places largely coal; nowhere workable.....	6
Coal.....	10
Shale.....	5
Total coal.....	2 7

Silvertip mine.—The Silvertip mine, which is on the west side of the field, about 2 miles south of the State line, is the only producing mine in the field. It consists of a slope about 300 feet long, from which two rooms have been turned off to the left. The total production up to July, 1907, is reported to be only 500 tons, but the size of the workings indicates a much larger production. The coal is mined by one or two men during part of the year, especially in winter, hoisted from the mine by a gasoline engine, and hauled in summer time by wagons to Garland and to the camps of the Reclamation Service at Corbett, Wyo., where it is sold for \$5 to \$6 per ton. The following are sections at this mine:

Sections of coal bed at the Silvertip mine, in NW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 25, T. 58 N., R. 100 W. (Wyoming).

MAIN ENTRY.		FIRST ROOM ON LEFT OF ENTRY.	
	Ft. in.		Ft. in.
Shale.....		Coal.....	8
Coal.....	1 3	Clay.....	1½
Shale.....	2½	Coal.....	2
Coal.....	8	Bone.....	2
Shale.....	½	Coal.....	8
Coal.....	2 1	Talcose material; white, greasy,	
Base not exposed.		crystalline, granular, soft.....	½
Total coal.....	4 0	Coal.....	4½
		Bone.....	2
		Coal, good, with three or four dis-	
		continuous ¼-inch films of clay.	2 1
		Total coal.....	3 11½

The quality of the coal has not been determined chemically, but probably it is similar to that of the same coal bed where it outcrops at Bridger, Mont. The coal bed is thicker and cleaner at Silvertip than it is at Bridger, and for this reason it would seem probable that extensive developments will follow.

BRIDGER COAL FIELD.^a

The most productive of the fields described in this paper is that lying along the west side of Clark Fork, in southern Montana. This field may be known as the Bridger coal field, from the name of the principal town and of one of the largest mines. The field extends from the south side of T. 7 S., R. 23 E. of the Montana meridian, northward for 25 miles. The part of the field treated in this report is bounded on the north by the north side of T. 4 S., R. 22 E., about 4 miles north of Joliet, Mont.

The coal beds are the same as those in the Silvertip coal field, belonging to the Eagle sandstone. They cross the State line from Wyoming in T. 9 S., R. 25 E. On the Wyoming side of the line these beds are not workable. West of Frannie, Wyo., they have practically disappeared, being represented only by a few thin layers of coal in a mass of black carbonaceous shale.

The southernmost point of workable coal is in the NW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 2, T. 9 S., R. 24 E., where the bed is exposed on both sides of a gulch that cuts deeply into the Eagle sandstone. On the north side of this gulch the following section was obtained:

Section of Eagle coal $4\frac{1}{2}$ miles west of Scribner, Mont., in sec. 2, T. 9 S., R. 24 E.

	Ft.	in.
Sandstone, massive, gray.....	27	
Shale, coaly.....	2	
Coal.....	6	
Bone.....	6	
Coal.....	2	
Shale, dark, coaly.....	2	
Alternating layers of sandstone and pale bluish-gray shale.....	15	
Total coal.....	2	6

The coal is exposed in two prospect drifts which have not been worked for many years. On the south side of the gulch the coal is not workable, being only 14 inches thick. Northward through T. 8 S., Rs. 23 and 24 E., the coals of the Eagle sandstone are too thin to work; but in T. 7 S., R. 23 E., they are of workable thickness.

^a The writer is indebted to N. H. Darton's paper on the Coals of Carbon County, Mont. (Bull. U. S. Geol. Survey No. 316, 1907, pp. 174-193), for supplementary data on this coal field.

In the NE. $\frac{1}{4}$ sec. 27, T. 7 S., R. 23 E., the following section of the coal bed was obtained:

Section of Eagle coal bed 7 miles south of Bridger, in sec. 27, T. 7 S., R. 23 E.

	Ft.	in.
Shale, carbonaceous.....	1	1
Bone.....		8
Coal.....	1	2

About one-fourth of a mile northwest of the point at which the foregoing section was obtained the following measurements were made:

Section of Eagle coal bed $6\frac{3}{4}$ miles south of Bridger.

Middle bed:	Ft.	in.
Coal.....	10	
Shale.....	2	
Coal.....	1	1
Shale, carbonaceous.....	4	
Coal.....	1	
Shale, carbonaceous.....	1	
Sandstone, shaly.....	2	
Coal, bony.....	1	3
Total coal.....	2	11

Lower bed:

Shale, carbonaceous.....	7	
Coal.....		6
Shale.....		1
Coal.....	1	
Total coal.....	1	6

Section of Eagle coal 200 yards south of preceding locality.

	Ft.	in.
Coal.....	1	1
Bone.....		8
Coal.....	1	2
Total coal.....	2	3

About 750 feet farther north there is a fault which trends N. 45° E., producing an offset of 1 mile in the outcrop of the coal bed. This fault has been traced from the southeast corner of sec. 15 for more than 2 miles southwestward, beyond the southeast corner of sec. 29. About 1 mile northwest of it is another fault trending about N. 65° E., with downthrow on the southeast side. Between these two faults is a depressed block of strata in which the coal bed is bent in a small flexure. Apparently the coal does not reach workable thickness in the block, the beds being in most places less than 2 feet thick. However, it is reported on good authority that the coal is over 2 feet thick at some places in this fault block.

About 1 mile farther north, in sec. 9, T. 7 S., R. 23 E., about $3\frac{1}{4}$ miles south of Bridger, the following section was obtained in an old prospect:

Section of coal bed in a prospect $3\frac{1}{4}$ miles south of Bridger, in sec. 9, T. 7 S., R. 23 E.

	Ft.	in.
Shale, sandy.....	2	
Coal.....		5
Clay.....		8
Coal.....	2	6
Total coal.....	2	11

North of this point the outcrop of the coal bed disappears beneath the alluvium of the Clark Fork valley. It reappears in the hills on the northwest side of the valley and runs along the cliffs northward across T. 6 S., R. 23 E. In the NE. $\frac{1}{4}$ sec. 29 the following section was made:

Section of coal bed 1 mile southwest of Bridger, in sec. 29, T. 6 S., R. 23 E.

	Ft.	in.
Sandstone, thin-bedded, yellow.....	5	
Sandstone, thin-bedded, and shale, carbonaceous, with coaly streaks.....	1	3
Coal.....	1	9
Shale.....		$1\frac{1}{2}$
Coal.....		8
Total coal.....	2	5

At the mine of the Bridger Coal Improvement Company, in the SW. $\frac{1}{4}$ sec. 17, T. 6 S., R. 23 E., 1 mile northwest of Bridger, the following section was measured:

Section of coal in Bridger mine.

	Ft.	in.
Coal.....	1	2
Shale.....		6-18
Coal.....	3	6
Shale and sandstone.....	1	
Shale.....		6
Coal.....	1	
Total coal.....	5	8
Sandstone, with a little shale.....	20	
Coal (reported as good blacksmith coal).....	1	9
Clay, white, soft.....		6-8

This mine was opened in 1897 and commenced shipping coal in 1898. It is worked by the long-wall method. A mining machine is used in driving air courses and gangways. In the deeper parts of the present workings, where the coal is about 800 feet deep, the roof pressure is

high and is utilized to some extent in the mining. When the working face of the coal is undercut and left for a few hours, the face breaks off extensively as a result of the roof pressure. Heavy timbering is required on the slopes. Mining is done largely by blasting down the coal with black powder; the coal is very hard and can usually be mined only by shooting. The mine employs about 100 men, working two shifts a day of eight hours each. The miners are paid \$1 per ton for mining coal. This is 25 cents per ton in excess of the wages paid to the miners at Bear Creek or Red Lodge, the higher price being due to the thinness of the bed at Bridger and to the fact that the coal is harder, which renders mining more difficult. The miners produce from 3 to 6 tons per day per man. The main slope has a length at the present time (1907) of 5,000 feet. This slope runs west-southwestward down the dip of the bed, which here amounts to 6° SW. The maximum output of the mine is about 250 tons per day. The coal is hoisted up the incline by a 250-horsepower electric hoist. The trains of coal cars, or trips, are coupled to an electric motor at the top of the slope, and drawn over a trolley line three-fourths of a mile to the tippie.

The coal is sold both as lump and nut coal. The egg and pea sizes go into the cars without being separated from the rest. The waste coal and slack is used in generating electricity. The quality of the coal at Bridger is practically the same as that of the coal in the other mines on the same bed, namely, the McCarthy and Gebo mines, near Fromberg; the Burgin mine, near Joliet, Mont.; and the Silvertip mine, in northern Wyoming. It is superior in many respects to the coal of the Fort Union and Laramie formations which is mined at Red Lodge and Bear Creek, Mont., and near Basin, Wyo. The superiority consists chiefly in its better keeping qualities, due largely to its hardness and compactness, and it is said that for this reason it sells in the Montana market for about \$1 per ton more than the Red Lodge and Bear Creek coals. The moisture content and fuel ratio are practically the same as in those coals, but the ash content is somewhat higher. The Bridger coal shows the first indication of slacking in about two months after it is mined, but the deterioration is not sufficient to affect the value of the coal for about one year. When kept in stock it is much less subject to spontaneous combustion than the Sheridan, Bear Creek, and other coals of the Fort Union formation. The partings of the coal bed thicken and thin, the middle parting decreasing from a maximum thickness of about 4 feet in the upper part of the mine to a minimum thickness of only 6 inches at the present working face. The miners believe that this indicates that the parting will disappear at a greater depth.

From Bridger the outcrop of the coal bed trends north-northwestward across T. 6 N. No prospects were noted in this township.

About 500 feet north of the northwest corner of sec. 6, T. 6 S., R. 23 E., a fault cuts the outcrop of the coal bed and produces an offset of nearly 2 miles. The trend of this fault is N. 52° E., and the downthrow is to the northwest. On the south side of the fault the coal is exposed in several places, but owing to the drag of the fault a good section could not be obtained. At one place 21 inches of coal was noted and at another 31 inches.

The nearest opening north of the fault line is the McCarthy mine No. 1. It is located in the SE. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 19, T. 5 S., R. 23 E., Montana, principal meridian. At one time as many as twenty men were employed here, but now the mine is shut down, as it can not compete with the McCarthy mine No. 2 and the Gebo mine, where the bed is thicker and nearer the railroad. Owing to caving of the mine, only 3 feet of coal was visible.

In a prospect hole in the SW. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 19, T. 5 S., R. 23 E., $1\frac{1}{4}$ miles southwest of Fromberg, a section of part of the coal bed is as follows:

Section of coal bed in a prospect $1\frac{1}{4}$ miles southwest of Fromberg.

Shale, sandy.	Ft. in.
Coal.....	1 4
Shale.....	1
Coal.....	6
Shale.....	$1\frac{1}{2}$
Coal.....	10+
Bottom not exposed.	
Total coal.....	2 8+

The following section was taken in a caved-in prospect hole about $1\frac{1}{4}$ miles south of west of Fromberg, in the NW. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 19, T. 5 S., R. 23 E.:

Section of coal bed in a prospect $1\frac{1}{4}$ miles west-southwest of Fromberg.

Shale, sandy.	Ft. in.
Coal.....	10
Shale.....	1
Coal.....	7
Shale.....	$1\frac{1}{2}$
Coal.....	1
Total coal.....	2 5

The strike of the bed is N. 25° W. and the dip is about 6° SW.

The McCarthy mine No. 2, also known as the Carbon mine, owned and operated by the Alba Coal Company, of Fromberg, is located in the SE. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 18, T. 5 S., R. 23 E. Twenty-five men are employed at this mine, and the coal is hauled in wagons to the railroad at Fromberg. The coal bed, which dips 5° W., is worked from two

openings about 500 feet apart. The southern opening runs N. 85° W. A section taken 700 feet in from the mouth of this opening is as follows:

Section of coal bed in south opening, McCarthy mine No. 2.

	Ft.	in.
Sandstone.		
Coal (poor, used as roof).....	3	
Coal, good.....		6
Bone.....		9
Coal.....	2	
Bone.....		6
Coal.....	2	4
Sandstone floor.		
Total minable coal	4	10

A fault of 3-foot throw was noted 300 feet in from the mouth of the first opening. It strikes north and south, with a downthrow on the west side. Several other faults were found farther in, according to Mr. Weber, one of the operators; but they have small throws and do not interfere with the mining of the coal.

The Gebo mine is located 1 mile west of Coalville (formerly called Gebo), Mont., in the NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 13, T. 5 S., R. 22 E. It is connected with the branch line of the Northern Pacific Railway by a spur from Fromberg, and is owned and operated by the Bituminous Coal Company.

This mine is worked by the room and pillar system. Up to the time of the writer's visit, the coal was mined by electric machines, but owing to a strike among the miners the machines were taken out and hand mining was adopted. The coal is hauled by an electric tramway out of the mine to a steel tippie three-fourths of a mile away. Electric power is used for tram, hoist, drilling, and ventilation. The output is 200 tons per day. The beds dips about 6° W. It is mined from three openings, one running northeastward and tapping a small outlying area called by the miners a "bench." At the working face of the northeast entry, 1,000 feet from the mouth, the following section was made:

Section of coal bed in northeast entry, Gebo mine.

	Ft.	in.
Coal, bony, used as roof.....	2	
Coal, good.....	1	1
Coal, bony.....	1	4
Coal, good.....	3	
Coal, bony, used as floor.		
Total minable coal	4	1

In the main slope, which runs westward under the bluff, the following section was taken 500 feet from the entrance:

Section of coal bed in main entry, Gebo mine.

	Ft.	in.
Bone, used as roof.		
Coal.....	1	6
Bone.....		6
Coal.....	3	6
Total coal.....	5	

The third opening, running northwestward, connects with the working of the main slope farther in. Electricity is used as power throughout the mine. A box-car loader was installed at the time of the writer's visit.

The strike of the coal strata is slightly west of north. In the SE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 36, T. 4 S., R. 22 E., the following section was obtained:

Section of coal bed $3\frac{1}{2}$ miles north of Coalville, in sec. 36, T. 4 S., R. 22 E.

	Ft.	in.
Sandstone, shaly.		
Coal, dirty.....	10	
Coal.....		6
Shale.....		1
Coal.....		8
Bone.....		4
Coal.....		2
Total minable coal	3	2

The Burgin mine, also known as the Squaw Smith mine, one of the oldest in the neighborhood, is located in the SE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 26, T. 4 S., R. 22 E., on the north bank of Elbow Creek, $2\frac{1}{2}$ miles south of Joliet, Mont. It is owned by the Joliet Coal and Fuel Company and is operated by Barrett Brothers. Formerly it supplied only the local demand, but since the extension of the railroad up Rock Creek coal is hauled to Joliet in wagons. Mining is done by hand, following the room and pillar system. The dip of the strata is 5° W.; the strike is north. The bed is said to improve in quality toward the west. The following is a section in this mine:

Section of coal bed in Burgin mine, 500 feet from entrance.

	Ft.	in.
Sandstone, shaly.		
Coal.....		2
Bone and dirt.....	1	5
Coal.....		4
Bone.....		2
Coal.....		6
Bone.....		8
Coal.....	1	4
Bone.....		6
Shale floor.		
Total minable coal	2	4

The Barrett mine, owned by the Montana Fuel and Iron Company and operated by the Barrett Brothers, of Joliet, is located in the NW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 25, T. 4 S., R. 22 E., about 2 miles south of Joliet. The coal output, which does not exceed 40 tons per day, is hauled in wagons to the railroad at Joliet. The strike of the rocks here is N. 5° E. and the dip 5° W. The following section was obtained in the mine about 250 feet from the mouth:

Section of coal bed in the Barrett mine.

Sandstone.	Ft. in.
Coal.....	2
Bone and dirt.....	10
Bone.....	11
Coal.....	1 2 $\frac{1}{2}$
Bone.....	6
Coal.....	1 2
Shale.	
Total coal.....	2 6 $\frac{1}{2}$

A shaft is being sunk in the SE. $\frac{1}{4}$ sec. 23, T. 4 S., R. 22 E., with the intention of reaching the Bridger coal bed. The location has the advantage of being nearer the railroad than the two mines last described. Two other openings are located in the NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 26, T. 4 S., R. 22 E., but owing to the thinness of the coal bed they were abandoned. The small mine one-half mile south of Joliet, on the south bank of Rock Creek, was abandoned for the same reason. It is several years since mining was carried on here and the slope is caved. In the NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 23, T. 4 S., R. 22 E., brick-colored fragments of sandstone point to a burning of the coal bed. Clinkers due to the above cause are rare in this field.

From Joliet northward the strike of the rocks is north and south; the dip immediately north of Joliet is 4° W., but decreases to 2° near the north line of the township. About a mile north of Joliet an old caved-in prospect was found, said to have produced coal at one time. It is the intention of the Barrett Brothers to reopen this if possible. The only prospect north of Rock Creek where a section could be obtained is located in the SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 1, T. 4 S., R. 22 E. The section is as follows:

Section of coal bed 2 $\frac{1}{2}$ miles north of Joliet, in sec. 1, T. 4 S., R. 22 E.

Sandstone roof.	Ft. in.
Coal.....	1 7
Clay.....	1
Coal, bony.....	6
Shale.	
Total coal.....	2 1

As the roof is excellent and the floor rather soft and easily picked, the mining of this coal could perhaps be carried on with profit in the future.

The following note on the prospect at Carbonado, on the Red Lodge branch of the Northern Pacific Railway, 8 miles west of Joliet, is quoted from N. H. Darton:^a

Several years ago a large shaft was sunk at Carbonado station to reach the Bridger coal bed. A preliminary drill hole was bored, which gave promise of a thick bed, but in the shaft the coal has a thickness of 4 feet with a parting, and occurs at a depth of about 980 feet. The enterprise belonged to the late Marcus Daly and was equipped for extensive workings. A very large amount of water was encountered, and as the bed was not satisfactory the project was abandoned.

QUALITY OF THE COAL.

The coals of the fields treated in this paper are all of the subbituminous class, often called black lignite, intermediate between true lignite and bituminous coal. They show no trace of woody structure. The Eagle coal compares favorably with other subbituminous coals of the Rocky Mountain region. The Laramie and Fort Union coals of the Bighorn Basin are of poorer quality.

PHYSICAL PROPERTIES.

The coal of the Eagle sandstone has similar physical properties in all parts of the field. The coals of the Laramie and Fort Union formations are variable in physical properties and differ markedly as a group from the Eagle coal. In general the Eagle coal is harder and more compact than the Laramie-Fort Union coals. As the coals contain practically equal amounts of water, the better keeping quality of the Eagle coal may be in part due to this superior hardness and compactness. The difference in hardness affects mining by making it necessary to blast all the coal that is removed. No coal can be removed by picking alone, as is done in some mines that work the higher beds. At the working face of the Bridger mine, on the Eagle coal, a strong blow of the pick results merely in shattering a little coal about the point struck. It is not possible to drive the pick on cleats and partings and pry out the blocks of coal. The Eagle coal is more brittle and less tough than the higher coals in the Laramie and Fort Union formations. The coals of both groups are about equally dirty to handle, leaving considerable smut on the fingers.

One of the most important physical differences between coals lies in their minute jointing—a property whose value in distinguishing coals of different quality has not been sufficiently recognized. The

^aBull. U. S. Geol. Survey No. 316, 1907, p. 192.

fine jointing of the Eagle coal of the Silvertip and Bridger fields approaches that of eastern bituminous coals, though it is not quite so closely spaced. The jointing of the Laramie-Fort Union coals, on the other hand, is much more imperfect than that of the Eagle coal, yet superior to that of coals of the same age near Sheridan, and to that of the coals of the other coal-mining regions of eastern Wyoming and Montana. As jointing and cleavage are doubtless results of rock pressure and are promoted by mechanical movement, the perfection of the jointing is to some extent an index of the pressures and movements to which the coal has been subject. The firmer and better bituminous and subbituminous coals have more highly developed jointing than poorer coals of the same groups, probably in part because they have been subject to greater pressure or more deformation. This may explain why jointing is more perfect in the Fort Union-Laramie coals of the Bighorn Basin, where the rocks are deformed, than it is in coals of the same age in the flat, undisturbed strata of the coal fields east of the Bighorn Mountains and in eastern Montana. Other differences in the coals of the two regions may be due to wholly unlike causes, such as the deposition of different vegetable materials or deposition under different conditions, but the important difference in jointing seems to be the effect of subsequent deformation or pressure on the coal. In like manner the difference in jointing between the Eagle coal of the Bridger field and the Fort Union coal of the Bear Creek-Red Lodge fields, a short distance to the west, may be assigned to the greater pressure which has been exerted on the former by an excess of load consisting of over 5,000 feet of strata, and to the post-Laramie pre-Fort Union deformation, which affected only the earlier coal.

The jointing of the Eagle coal is rectangular. It tends to divide the coal into small, roughly cubical blocks, with smooth, shiny faces. The little cubical blocks are larger than those common to most of the bituminous coals of the Appalachian province, owing to the wider spacing of the cleavage. Within each block the fracture is conchoidal, but the conchoidal breaks are not conspicuous, owing to their small size and to the prominence of the rectangular joints. Joints parallel to the bedding are not so prominent as either of the two sets of joints normal to the bedding.

The jointing of the Laramie-Fort Union coals of the Bighorn Basin is irregular and poorly developed. At places cubical jointing is noticeable, but it never has the perfection of that in the Eagle coal. Parting parallel to the bedding is conspicuous. In the Rogers & Gapin mine, 7 miles southeast of Basin, this parting parallel to the bedding is so pronounced that the coal breaks out in flat slabs, which

are in marked contrast with the more equidimensional lumps of the Eagle coal from the Silvertip and Bridger mines.

Most of the Fort Union-Laramie coals on the east side of the Bighorn Basin are finely banded. At the Rogers & Gapin mine the coal is composed of thin layers of bright, shiny coal of vitreous luster, alternating with less conspicuous, thinner layers of dull, lusterless coal. The bright layers predominate.

The Eagle coal is banded in a similar way, but the structure is not nearly so conspicuous. The bright bands are not so bright as those of the higher coals, and they have a pitchy or varnish-like luster. The intervening bands are not so dull as the similar bands in the Fort Union coal, but they have a faint, satiny luster. As a result of those differences the banding of the Eagle coal is less conspicuous. The effect is intensified by the spreading of a sheen over some faces of Eagle coal, possibly the result either of slight shearing or of the deposition of a lustrous coaly substance on those faces. Faces having this sheen do not exhibit the banding as clearly as other faces in the same specimen that lack it. This feature has not been observed in any of the Laramie or Fort Union coals.

The color of the Eagle coal is always jet-black. That of the Laramie-Fort Union coals ranges from jet-black to brownish black. The streak of the Eagle coal is dark brown on a white plate; that of the Laramie-Fort Union coals is also dark brown, but of a lighter tint. When scratched with a knife, none of the coals shows a pulverulent streak, but one that is shiny, greasy, dark brown, almost black.

The coals are said to be more easily ignited than eastern soft coals and to burn with longer, smokier flames. The Eagle coal has a shorter, bluer flame than the Laramie-Fort Union coal and is more satisfactory for use under locomotive and other strong-draft furnaces, because less of the coal is blown out by the draft. A locomotive burning either coal emits a shower of glowing cinders greatly in excess of that seen behind the funnel of a locomotive that is burning eastern coal.

In their weathering and keeping properties lies the most important commercial difference between the two groups of coals. The Eagle coal may be kept in stock for a year or more without much deterioration; the Laramie-Fort Union coals begin to slack in one month, and in a year are likely to be reduced to a mass of small pieces. Moreover, the latter are more subject to spontaneous combustion.

CHEMICAL PROPERTIES.

The chemical character of these coals is indicated by the subjoined analyses:

Analyses of coal samples from Basin, Wyo., and Bridger, Mont., coal fields.

[F. M. Stanton, chemist in charge.]

Laboratory No.....	Basin, Wyo. (Fort Union).	Bridger, Mont. (Eagle).				
	5778.	5495.	3955.	3956.	5508.	3954.
Sample as received:						
Prox. Moisture.....	14.94	14.83	8.47	8.70	9.76	8.93
Prox. Volatile matter.....	33.43	26.93	31.47	34.03	27.66	33.43
Prox. Fixed carbon.....	37.90	44.89	41.88	49.07	46.16	46.92
Prox. Ash.....	13.73	13.35	18.18	8.20	16.42	10.72
Ult. Sulphur.....	1.76	.33	.84	.63	.63	.61
Ult. Hydrogen.....	5.68	5.61	.....	.....	5.09	.....
Ult. Carbon.....	53.27	57.05	.....	.....	56.19	.....
Ult. Nitrogen.....	1.02	.91	.....	.....	1.01	.....
Ult. Oxygen.....	24.54	22.75	.....	.....	20.66	.....
Calories.....	5,281	5,576	.....	.....	5,686	.....
British thermal units.....	9,506	10,037	.....	.....	10,235	.....
Loss of moisture on air drying.....	4.60	8.80	3.20	3.10	3.70	3.60
Air-dried sample:						
Prox. Moisture.....	10.84	6.61	5.44	5.78	6.29	5.53
Prox. Volatile matter.....	35.04	29.53	32.51	35.12	28.72	34.68
Prox. Fixed carbon.....	39.73	49.22	43.27	50.64	47.94	48.67
Prox. Ash.....	14.39	14.64	18.78	8.46	17.05	11.12
Ult. Sulphur.....	1.84	.36	.87	.65	.65	.63
Ult. Hydrogen.....	5.42	5.08	.....	.....	4.86	.....
Ult. Carbon.....	55.84	62.55	.....	.....	58.35	.....
Ult. Nitrogen.....	1.07	1.00	.....	.....	1.05	.....
Ult. Oxygen.....	21.44	16.37	.....	.....	18.04	.....
Calories.....	5,536	6,114	.....	.....	5,904	.....
British thermal units.....	9,964	11,005	.....	.....	10,629	.....

5778. Seven miles southeast of Basin, Wyo. Collected by C. A. Fisher, 1907.

5495. One mile west of Bridger, Mont. Collected by C. W. Washburne, 1907.

3955, 3956. One mile west of Bridger, Mont. Collected by N. H. Darton, 1906.

5508. Coalville, Mont. Collected by M. A. Pishel, 1907.

3954. One mile west of Fromberg, Mont. Collected by N. H. Darton, 1906.

An air-dried sample of Fort Union coal has a calorific value of 9,964 British thermal units; similar samples of Eagle coal show 11,005 and 10,629 British thermal units. The superiority of the Eagle coal is further indicated by the higher content of fixed carbon and lower content of sulphur.

CONDITIONS OF MINING.

The gentle dip of the minable coal in these fields is favorable to development. The amount of water is not great, but in some localities, especially in the Silvertip field, it necessitates pumping. Near Fromberg and Coalville the amount of water that enters the mines is so small that it is drawn out in water cars attached to the regular trips. Dust is always present in the dry mines, but not in dangerous quantities. Gas is not troublesome. Open lamps are used in all the mines, but there have been no explosions. Practically no mine timber is produced in the region. Yellow pine and fir shipped in from the outside cost, in 1907, about \$25 per 1,000 feet B. M.

Labor conditions are similar to those in the other camps in Montana and Wyoming. The miners are mostly foreigners, largely Roumanians and Cornishmen. They receive from 75 cents to \$1 per ton for hand mining, the higher prices prevailing in mines that work the Eagle coal. The miners make from \$4 to \$6 per day. Machines were formerly used in the mines near Fromberg, but after a strike in 1907 they were taken out on demand of the miners. The workmen are well organized in unions under the control of the Western Federation of Miners.

TRANSPORTATION.

The mines in the Bridger and Garland coal fields are close to railroads. The Northern Pacific Railway carries the product of the former field, and the Cody branch of the Burlington Railroad will be the carrier for the Garland field when its coal is shipped. The Silvertip coal field could be easily reached by a 15-mile spur of gentle grade, built up the valley of Silvertip Creek from the Yellowstone Park Railroad near Belfry, Mont. At present the small output of this field is hauled by wagon about 18 miles to Garland and neighboring towns.

The best part of the Basin coal field is only 1 mile from the Kirby extension of the Burlington Railroad. At present the output of the only productive mine, the Rogers & Gapin, is hauled 10 miles by wagons, across a ford in Bighorn River, to Basin.

FUTURE DEVELOPMENT.

The Bridger coal field is now producing about 105,000 tons per year. This output can be increased by the opening of a few new mines. Yet the present state of development is as high as that of most of the western coal fields. None of the mines, except the Bridger, are worked to more than a small part of their capacity.

The poor quality and small amount of coal in the Basin field make extensive developments improbable. Coal from Sheridan, Wyo., competes with it successfully at Basin, in spite of the longer haul and higher price. The same statement will hold good for the Garland coal field. Both fields will probably be worked on a small scale, and only for local use.

The Silvertip field, on the other hand, contains thick beds of good coal in sufficient quantity to justify the building of a railroad from the vicinity of Belfry, Mont. Large mines will probably be opened in this field.

COAL FIELDS OF THE SOUTHWEST SIDE OF THE BIGHORN BASIN, WYOMING.

By E. G. WOODRUFF.

INTRODUCTION.

The paper here presented is a preliminary report of a detailed reconnaissance survey of the coal fields of the southwest side of the Bighorn Basin in Wyoming.^a C. A. Fisher exercised general supervision over the work and J. Ernest Carman and E. L. De Golyer assisted the writer in collecting the data here set forth. The primary purpose of the survey was to determine what lands in the area are underlain by coal and to segregate and classify such lands by legal subdivisions (40-acre tracts). Land surveys were used as a basis of the work.

In the field work, surveys were tied to land corners that were located by meandering such lines across each township in east-west or north-south directions. Where rough topography prevented the usual method, irregular traverses were made, and connected to land corners wherever possible. Coal outcrops were meandered and located with reference to land corners and sections were measured at short intervals. The locations of the coal outcrop and of part of the sections measured are shown on Pl. XI. It should be noted that the land corners between Tps. 44 and 45 N. and between Tps. 52 and 57 N. are not well marked, and many of the corner stones and posts are not in proper place; consequently less dependence should be placed on that part of the map which represents those areas than on other parts.

LOCATION AND EXTENT.

The coal fields described in this report are situated on the southwest side of the Bighorn Basin at the base of the Shoshone-Rattlesnake Mountain Range. They form a zone of irregular outline from 6 to 15 miles wide, extending from a point 2 miles north of Clark Fork of Yellowstone River 110 miles southeastward to Bighorn River, near Kirby. As shown on Pl. XI, they comprise an area of about 1,300 square miles. The chief towns in the area are Cody, the terminus of the

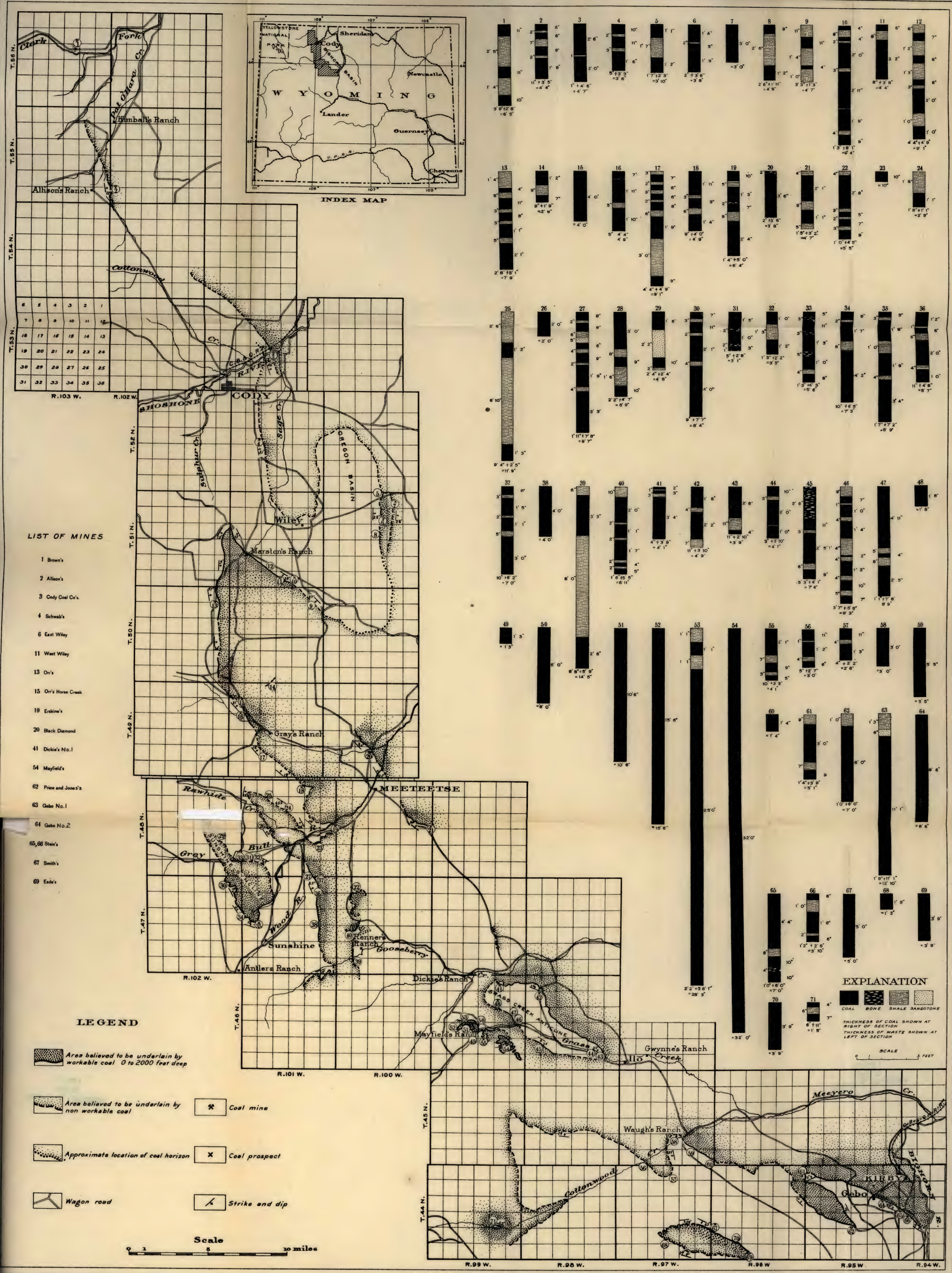
^a A detailed report is now in course of preparation and will be issued as a separate bulletin.

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Note: The boundaries of private tracts established by resurveys are not shown on the map.

Cody branch of the Chicago, Burlington and Quincy Railroad; Meeteetse, an inland town on Grey Bull River; and Kirby, a railroad station near the Gebo mines, at present the terminus of the Worland-Kirby extension of the Burlington Railroad. Coal beds which have sufficient thickness and extent to be of local interest are distributed throughout the fields, but deposits of commercial importance lie mainly in the southern part of the basin.

SURFACE FEATURES.

The area is characterized mostly by hilly topography. It lies on the edge of a broad structural basin, in a zone between mountain and plains, where the strata which are upturned along the mountains are being rapidly eroded. These conditions have produced sharp strike ridges which in general parallel the main uplift or encircle small outlying anticlines or domes. The field is crossed at short intervals by narrow valleys cut by rivers or creeks which rise in the mountains and flow eastward into the basin. The general topographic features are modified by many badland areas, plateau remnants, and small erosional basins. In the northern part of the area Heart Peak rises as an isolated mountain, 3,000 feet above the general level. The altitude of the field averages about 5,000 feet, but ranges from 4,000 feet on Clark Fork to 8,000 feet on Heart Peak, and 8,200 feet in the southwestern portion of the area. Variations in altitude of 200 to 500 feet in a horizontal distance of one-fourth mile are not uncommon, and at many places cliffs rise almost perpendicularly 100 to 400 feet.

The fields are drained by three rivers and many smaller streams which rise in the mountains and flow eastward, crossing the fields in their passage to Bighorn River, which is the trunk stream of the basin. Clark Fork, the northernmost of these rivers, flows eastward, then northeastward beyond the boundaries of the area mapped; Shoshone River crosses the area near Cody in a gorge 100 to 150 feet deep; and Grey Bull River, south of the center, is a swiftly flowing stream with narrow flood plains bordered by rugged areas. Bighorn River forms the southeastern limit of the territory examined in 1907. Between the rivers are minor streams, notably Pat O'Hara, Sage, Meeteetse, Gooseberry, Grass, and Cottonwood creeks. All the streams are in a youthful stage of erosion, generally with entrenched valleys and basins having moderately steep slopes from the stream courses to the inter-stream divides.

GEOLOGY.

STRATIGRAPHY.

GENERAL SECTION.

The sedimentary rocks outcropping in these coal fields comprise an extensive series of rocks ranging from Carboniferous limestone to the Wasatch formation. In general the beds outcrop in a series of bands forming a regular succession from the "Red Beds" at the base of the mountains eastward to the badlands of the Wasatch. A section of the strata measured at Cody, where the beds are clearly exposed, is set forth in the following table:

Section of coal-bearing and associated rocks exposed along Shoshone River near Cody, Wyo.

System.	Formation.		Thickness (feet).	Characteristics.
Tertiary.	Wasatch formation.			Various colored shales interbedded with sandstone and conglomerate.
	Unconformity.			
	Fort Union formation.		3,100	Gray to drab sandy shale and tan-colored massive sandstone. In the lower part of the formation conglomerates occur at intervals through 1,000 feet of strata.
	Unconformity (?)			
Cretaceous.	Laramie (?) formation.		2,630	Dull green sandy shale with local brown leaf-bearing beds and gray massive sandstone.
	Montana group.	Undifferentiated Montana.	760	In lower part gray massive sandstone and dark-colored sandy shale in alternating layers; in upper part dark and light gray shales alternating, and numerous lignitic beds.
		Eagle sandstone.	220	Gray massive sandstone, weathering tan, and gray sandy shale with dark coaly bands. Locally coal-bearing.
	Colorado shale.		3,375	Black to dark gray shale with rusty sandstone at base and gray massive sandstone at short intervals in lower half. Thin beds of coal occur a little below the middle.
	Cloverly formation.		300	Gray, green, and maroon shales and gray compact sandstone.

As shown in the above table, the thickness of sandstone and shale between the top of the Colorado formation and the great unconformity at the base of the Wasatch formerly mapped by Fisher^a as "Laramie and associated formations" is here tentatively subdivided into Eagle, undifferentiated Montana, Laramie(?), and Fort Union. These formations are suggested on lithologic and paleontologic evidence, which, however, is not sufficiently conclusive for final decision. At the beginning of the field season, in the absence of definite fossil

^a Fisher, C. A., Prof. Paper U. S. Geol. Survey No. 53, 1906, p. 8.

evidence, differences in lithology alone were accepted as a basis for the subdivision into formations. A subsequent study of the fossils, both in the field and in the laboratory, by T. W. Stanton and F. H. Knowlton, has shown that the lithologic units do not coincide in all particulars with the formations as they are recognized farther north and elsewhere. Fossils collected at various localities in the fields point to the presence of the Eagle and Laramie formations, though the evidence is not conclusive, as many of the species are either new or heretofore unknown to the formations, and strictly characteristic specimens are lacking. A fresh-water fauna which contains forms suggestive of upper Montana occurs in beds between the Eagle and Laramie(?). There is abundant fossil evidence to prove the presence of the Fort Union formation. A suggestive break occurs at the base of the conglomerate beds noted in the table, which was thought in the field to be an unconformity at the base of the Fort Union, but later study of the plant collections shows that Fort Union forms occur a few feet below this horizon. As the final determinative evidence has not been obtained, the divisions shown in the table are only provisionally introduced.

Of the seven formations shown in the table only four, the Colorado, Eagle, Laramie(?), and Fort Union, are coal bearing; and the Cloverly, which seems to include at least part of the coal-bearing Kootenai formation of Montana,^a is barren in the field here discussed.

COLORADO SHALE.

The Colorado shale consists mainly of gray to black shale 3,375 feet thick, as measured at Cody, with massive rusty sandstones in the lower part and a mass of tan-colored sandy shale 200 feet thick forming the upper part.^b Broad strike valleys bordered by sharp ridges constitute the characteristic topographic expression of this formation where it is exposed along the west side of the area. Thin beds of coal interbedded with massive sandstone occur in the lower part of the formation. A bed 8 inches thick outcrops on a branch of Pat O'Hara Creek near Allison's ranch, and another 6 inches thick occurs in the bluffs along Shoshone River a short distance above the Cody bridge. Exposures of coal in the Colorado were noted at many points in the field, but none approaches workable thickness.

MONTANA GROUP.

In the northern part of Montana this group is subdivided into Eagle, Claggett, Judith River, and Bearpaw. Of these subdivisions the Eagle is the only one recognized in the area under discussion.

^a Fisher, C. A., *Econ. Geology*, vol. 3, 1908, pp. 77-99.

^b Fossils were collected in 1908 from the upper sandy shale in the southeastern part of the Bighorn Basin. T. W. Stanton states that "These fossils are more closely related to the Montana fauna than to the Colorado." It is probable, therefore, that a part if not all of this shale belongs to the Montana group.

The remaining formations are thought to be represented, but there is not sufficient evidence at hand to identify them positively. Therefore the group is presented in this report as Eagle and undifferentiated Montana.

EAGLE SANDSTONE.

The Eagle sandstone is recognized in the west side of the Bighorn Basin on stratigraphic and lithologic and not on paleontologic evidence. The fossil plants that were collected from this formation are either new or not sufficiently typical to prove its age conclusively. The formation is rather definitely identified, however, both by its stratigraphic position immediately above known Colorado shale and by its lithologic characteristics. In all essential particulars the formation resembles the Eagle as it is recognized 20 miles to the north, in the Clark Fork valley. It consists of massive sandstone and sandy shale with carbonaceous and coal beds. A section of the formation measured on Shoshone River 3 miles northeast of Cody is as follows:

Section of Eagle sandstone exposed along Shoshone River 3 miles northeast of Cody, Wyo.

	Feet.
Shale, drab, containing a few iron concretionary layers, also a 12-inch bed of coal	22
Sandstone, gray, massive	5
Sandstone and shale with dark coaly bands, in alternating layers	65
Sandstone, gray, massive	28
Sandstone, greenish, shaly at base	33
Sandstone, gray, massive, concretionary, weathering tan	65
	218

The Eagle is usually characterized by two massive sandstones from 25 to 65 feet thick, which weather into bold cliffs. These sandstones serve as guides to the location of the coal horizon which occurs between them. Coal of workable thickness is not continuous, however, at this horizon, but varies locally. In general character the formation remains fairly constant throughout the field, except in the extreme southern part, where it is slightly thicker and contains a greater number of beds, none of which is so massive as those to the north.

UNDIFFERENTIATED MONTANA.

As considered in this report the upper or undifferentiated part of the Montana consists of gray sandstone and dark-colored shale in alternating layers. It generally maintains a thickness of about 750 feet throughout the field except near Meeteetse, where the formation seems to be much thicker. Fossils collected from these beds include forms similar to those found in the Judith River formation of Montana. Insufficient evidence exists, however, to differentiate the formations recognized to the north, hence only the group name is here applied. The upper limit of the group is drawn on lithologic grounds

at the top of the massive sandstones. Above the boundary line the shale members are gray and contain thin coal beds and lignitic layers.

The formation contains no workable coal beds. Carbonaceous shale and coal beds are exposed in many of the outcrops, and near the west end of the Grass Creek basin the lower sandy member of the formation contains a bed of coal 18 inches thick. The undifferentiated Montana, however, contains no coal of commercial importance.

LARAMIE(?) FORMATION.

Overlying the Montana group is a series of sandstones and shales containing beds of coal and lignite. This formation, which is 2,630 feet thick where it is exposed on Shoshone River, is composed of two parts. The lower part consists of 980 feet of dark and light gray sandy shales, with a few rust-colored layers and numerous beds of coal and lignite. The carbonaceous beds are so numerous that they give a distinctly banded appearance to the shale. The upper part consists of dull green sandy shale with local brown leaf-bearing beds and gray or dull green massive sandstone.

Fossils collected from these beds were examined by T. W. Stanton, who reports that the species found belong to a fauna characteristic of the "*Ceratops* beds." As the stratigraphic position of these beds is not definitely determined, the name Laramie is applied, because the Laramie formation occupies a position in the geologic column between the Montana and Fort Union. Furthermore, it is thought best not to introduce a new name for these beds because they are a part of the series which is known in the literature of the region as the Laramie formation. The name, however, should not be considered as indicative of a positive correlation with beds of Laramie age to the south. Lenticular coal beds are exposed in this formation at various places throughout the field.

FORT UNION FORMATION.

The upper coal-bearing formation consists mainly of soft shale and massive sandstone with conglomeratic beds in the lower part. Where it is typically exposed along Shoshone River northeast of Cody it consists of three members. At the base there are about 1,000 feet of gray massive sandstone and green shale with coaly layers and numerous beds of conglomerate throughout. This member is overlain by 1,700 feet of soft sandstone and somber-colored shale in alternating layers, some of which contain coal beds. At the top of the formation there are 400 feet of gray sandy shale with local beds of sandstone.

Fossils collected at various horizons in this formation have been examined by T. W. Stanton and F. H. Knowlton, who report them to be characteristic of the Fort Union. A few fossil plants were found in a sandstone immediately below the conglomerate beds and

lower than the apparent unconformity previously mentioned. According to F. H. Knowlton these plants are Fort Union forms, and if further study confirms this opinion, the Fort Union probably includes several hundred feet of beds which are considered Laramie in this report, and the thickness of the Laramie is correspondingly thinner than is shown in the table.

STRUCTURE.

The coal fields here described lie on the edge of a broad structural basin where the beds dip gently to the east or northeast and strike parallel to the main uplift of the mountains to the west and southwest. This simple, moderately inclined structure is interrupted by minor folds which parallel the major structure and involve the coal-bearing rocks in a series of anticlines and synclines. The anticlines are gently arched and have the steeper side facing the mountains and more gentle slopes toward the basin. The synclines form shallow structural depressions about equal in extent to the anticlines.

Erosion has acted unequally on different parts of the folds. It has cut away the top of the anticlines and exposed Colorado shale in the interior, encircled by escarpments of the higher formations. The synclines have been affected to an equal extent, leaving outliers of coal-bearing rocks in plains of Colorado shale. The position of the outcrop of the coal beds in each field is dependent chiefly on the structure.

To the north of the Cody field the coal beds are included in the normally eastward-dipping strata. On Shoshone River they occupy the east flank of a small anticline. Along Sage Creek the beds appear in the west limb of a syncline, pass around its southern point, and after encircling the Oregon Basin outcrop in the west side of Frost Ridge. In the Meeteetse field the structure is complicated. The coal beds are included in normally dipping strata from the Meeteetse Rim southeastward to Grey Bull River and across the lower course of Meeteetse Creek. The coal-bearing rocks are included in the Upper Buffalo Basin anticline, a small uplift at Renner's ranch, and a fold along Wood River. Coal beds are also included in a number of structural depressions, notably the Sunshine syncline, the trough crossed by Rawhide Creek, and the syncline north of Renner's ranch.

In the Grass Creek field the outcrop of the coal beds encompasses an irregular uplift extending from Dickie's ranch to Ilo. Beds of coal are also found in a small syncline at Mayfield's ranch.

In the Gebo field a strike ridge locally variable in direction extends westward from Bighorn River to the east line of T. 45 N., R. 99 W., where it swings to the south and joins a small anticline along Cottonwood Creek. In the eastern part of T. 44 N., R. 99 W., the rocks are brought up into a small anticline which exposes coal beds in the

valley of Cottonwood Creek. A small syncline encompassed by coal beds lies in the southern part of the field and another of similar size forms a spur from the main body of coal-bearing rocks, 3 miles southeast of Gebo. Further details of the structure are presented on Pl. XI.

THE COAL.

GEOLOGIC OCCURRENCE.

In the western part of the Bighorn Basin coal of workable thickness occurs in three formations—the Eagle, Laramie (?), and Fort Union. The Eagle coal occurs mainly at one horizon, between the two massive sandstones comprising this formation. Generally this coal is below the limit of workability, but locally it is of sufficient thickness to be of importance. There are a number of small mines and prospects in the Eagle formation throughout the field, and the only commercial mines in the Bighorn Basin are in this formation in the vicinity of Gebo. In one of these mines the coal locally reaches a thickness of 11 feet.

The coal beds of the Laramie (?) formation occur in rather small lenses, which in few places form a continuous outcrop for more than 1 mile and which are workable for a much shorter distance. There is, however, northeast of Cody an exceptionally extended bed which has been prospected at intervals for 7 miles along its outcrop by the Cody Coal Company and others. Numerous partings of bone and shale separate the beds into benches generally less than 1 foot thick. The Laramie (?) coals are not mined at present, though there are some abandoned mines and many prospects.

The Fort Union formation contains some of the best and thickest coal beds in the western part of the Bighorn Basin. The beds, like those of the Laramie (?), are lenticular, but they are thicker and contain fewer partings. In the Mayfield syncline there are three beds, one of which is reported as containing 32 feet^a of good coal. The Black Diamond mine, near Meeteetse, is operated throughout the year on a bed of coal of this age.

The location of the mines and prospects and sections representative of local conditions are shown on Pl. XI.

GENERAL MINING CONDITIONS.

There are a few commercial and many small mines and prospects in the area. Three of the largest mines located near Gebo are being extensively developed since the building of the Burlington Railroad into the field during the fall of 1907. Two small commercial mines near Meeteetse supply the local trade in Grey Bull Valley. Many

^a During the fall of 1907, 24 feet of coal in a single bench was exposed in a prospect the bottom of which was filled with water. Mr. Mayfield, who owns the property, states that the total thickness is 32 feet.

small mines are operated chiefly by ranchmen to procure fuel for private use.

All the mines are operated by the room and pillar system. They are dry and contain only small quantities of gas; hence pumping and safety lamps are unnecessary. Generally the coal is mined by "bearing in" at some convenient dirt band and shooting it down with black powder. Most of the mines employ horse haulage, but some of the more recently developed mines are installing cables in the main gangways.

COAL FIELDS.

To facilitate description the area may be divided into four fields, which in a general way coincide with four drainage basins. Except for minor modifications they also agree with divisions adopted by Eldridge^a and Fisher.^b They are the Cody field, Meeteetse field, Grass Creek field, and Gebo field. A possible fifth field includes the valley of Clark Fork, but as that region contains only one abandoned mine and no exposures of coal that promise future development it is not treated in this report.

CODY FIELD.

The Cody field lies mainly in the Shoshone River valley. It is limited on the south by the Meeteetse Rim and to the north extends a short distance beyond the divide which culminates in Heart Peak. In this district coal occurs in the Eagle and Laramie (?) formations. It has been mined from the Eagle at the Allison, Schwab, and Wiley mines and from the Laramie (?) at the mine of the Cody Coal Company.

Allison mine.—The Allison mine is located in the NE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 25, T. 55 N., R. 102 W., on the east side of Skull Creek, a branch of Pat O'Hara Creek. An entry has been driven for about 100 feet on beds which dip 23°. One room has been opened from the entry and about 250 tons of coal taken out for use at neighboring ranches. It is a good subbituminous^c coal suitable for domestic purposes. The coal lies beneath a thin shale bed, which in turn is covered by a massive sandstone. Section No. 2 on Pl. XI shows the character of the bed at the mine where the most favorable conditions are presented. The bed is thinner along the strike on both sides of the mine.

Navine mine.—The Navine mine, 3½ miles northeast of Cody, formerly supplied a domestic trade in the Shoshone Valley. The mine is now abandoned and the roof so badly caved that a section of the bed could not be measured, and the previous extent of the mine was not determined.

^a Eldridge, G. H., Bull. U. S. Geol. Survey No. 119, 1894, p. 54.

^b Fisher, C. A., Prof. Paper U. S. Geol. Survey No. 53, 1906, p. 46.

^c The name subbituminous has recently been adopted by the United States Geological Survey for the class of coal above the brown lignites and below the bituminous coals—the class generally called "black lignite."

Cody Coal Company's mine.—During the season of 1905 the Cody Coal Company opened a mine 3 miles northeast of Cody, where Laramie (?) beds are exposed in a bluff along the Burlington Railroad about 30 feet above the track. The coal occurs in two benches, 24 and 30 inches thick, separated by a thin parting, and dipping 56° E. A main entry has been driven about 200 feet to the north along the strike and is intersected at the end by a slope sunk from the top of the terrace. The slope extends about 75 feet below the main entry and has small rooms opened near the bottom. Horsepower machinery was installed, and a few hundred tons of coal were taken out prior to the closing of the mine in 1907. The coal is subbituminous, with a black color, pitchy luster, and moderate hardness. A section of the bed is No. 3 on Pl. XI.

To the north for a short distance the bed is covered by gravel. Where it is exposed again at the old Navine mine conditions are unfavorable for extensive development. To the south, across Shoshone River, an attempt at mining has been abandoned. Beyond this point further examination of the bed is prevented by a cover of gravel.

Schwab mine.—The Schwab mine, formerly known as the Burns & Rogers mine, is 5 miles southeast of Cody, in the NW. $\frac{1}{4}$ sec. 21, T. 52 N., R. 101 W., on the east side of the stage road from Cody to Meeteetse, where the steeply dipping Eagle sandstone forms a prominent strike ridge. Starting on the outcrop of the coal a slope has been driven for 75 feet on a bed which dips 51° , and three entries have been opened to the south—one 10 feet long, another 15 feet, and a third 50 feet. The mine equipment consists of two small mine cars, a cable, and a horsepower whim. Two men are employed at this mine during part of the winter months, and the output is small, not exceeding 100 tons a year. Lump coal is sold at the mine for \$4 per ton. The coal is subbituminous, and is suitable for domestic uses. It has been so badly crushed in the upturning of the beds that a considerable percentage is too fine for the domestic market. A section of the bed at this mine, as shown in No. 4 on Pl. XI, contains 39 inches of coal in three benches. About 500 feet to the south the bed is not so thick, and to the north it is covered by valley wash. At this mine conditions are unfavorable for extensive development.

East Wiley mine.—A small mine, known as the East Wiley, has been opened in the Eagle sandstone on the east side of the Oregon Basin, in the NE. $\frac{1}{4}$ sec. 10, T. 51 N., R. 100 W. It consists of a 22° slope 200 feet long, with one small room at the bottom. The section (No. 6, Pl. XI) measured at this mine shows a total thickness of 42 inches in three benches, which are separated by two partings of shale, the larger being 2 inches thick. Other sections of the bed, both to the north and to the south of the mine, are shown on the same plate. It is estimated that 200 tons of good subbituminous coal has been taken from this mine to supply local ranch trade.

West Wiley mine.—The West Wiley mine is located southwest of the Oregon Basin, at the base of Frost Ridge, in the SE. $\frac{1}{4}$ sec. 34, T. 51 N., R. 101 W. It consists of a slope 195 feet long, with two small rooms at the bottom. At this mine the beds dip 28° . The coal occurs in two benches separated by a layer of carbonaceous shale. In the east room the lower bench is 38 inches thick and the upper bench 6 inches. In the west room, however, the thickness of the lower bench is not so great. Section No. 11, Pl. XI, is representative of the best conditions in this mine. The mine is located near the western edge of a lenticular bed. The bed contains 8 feet of coal where it is exposed in a ravine one-eighth of a mile to the east, and a short distance farther east it passes below workable limits. To the west the beds are variable and probably workable at several points between the mine and Sage Creek.

The mine is operated chiefly to supply coal to the Bighorn Basin Development Company, which is constructing extensive irrigation works in the vicinity. A small part of the coal is sold for domestic purposes at \$3 per ton. The annual production is about 150 tons. The coal has a brownish-black color, pitchy luster, and moderately smooth joints where not affected by slickensiding. It has been badly crushed, however, by the uplift of the beds, and as a consequence breaks irregularly and yields a high percentage of fine coal in mining.

Orr's mine.—Orr's mine is on the west limb of a syncline lying between the Oregon Basin and Sage Creek, in the NW. $\frac{1}{4}$ sec. 12, T. 50 N., R. 102 W. It is near the crest of a hogback of Eagle sandstone that dips 47° . A drift has been driven for 125 feet along the strike and a small amount of coal taken out, mostly from an open pit which has not reached below the zone of weathering. A section of the coal bed is shown in No. 13, Pl. XI. The large number of partings and the steep dip of the strata preclude extensive development at this mine.

Prospecting.—Some prospecting has been done in the northern part of the Cody field near Heart Peak and at several places northeast of Cody. The part of the district lying north of Shoshone River seems to contain very little workable coal, and even where the coal beds are of sufficient thickness to be minable the steep dip of the strata prevents extensive development.

South of the river prospecting has been done at various places, notably east of the Oregon Basin and along Frost Ridge. At the former locality the coal appears to have a sufficient thickness and favorable attitude for the opening of small mines. On the north side of Frost Ridge also there are several promising locations. The bed mentioned as exposed in a gulch south of the West Wiley mine,

where the coal is locally thickened, is the most favorable undeveloped deposit in the Cody district. To the southwest, on the opposite side of Frost Ridge, there will probably be very little mining.

MEETEETSE FIELD.

The Meeteetse field lies mainly in Grey Bull Valley. It extends from the Meeteetse Rim on the north to Gooseberry Creek on the south. Unequal erosion of the complex folds has greatly extended the outcrop of the coal-bearing beds by bringing them to the surface around a number of synclines and anticlines. Coal is mined in the Eagle and Fort Union formations and has been prospected in the Laramie (?). It is a good variety of subbituminous coal.

The Black Diamond and Erskine mines are operated throughout the year to supply the local trade in Grey Bull Valley, and other small mines at various places furnish coal to adjacent ranches.

Conie mine.—The Conie mine, on an isolated portion of the Meeteetse Rim, in the NW. $\frac{1}{4}$ sec. 4, T. 49 N., R. 101 W., is now abandoned after unsuccessful attempts at operation. The coal lies between beds of soft shale and is difficult to mine. Section No. 14, Pl. XI, was measured at this mine.

Orr's Horse Creek mine.—A mine formerly operated by Mr. Orr is situated on Horse Creek, about 3 miles northwest of Gray's ranch, in the NE. $\frac{1}{4}$ sec. 7, T. 49 N., R. 101 W. It consists of a well-timbered drift about 200 feet deep, from which entries have been turned. At the time this mine was examined it was not in operation and was partly filled with water, hence the extent of the workings could not be determined. It is known, however, that several hundred tons of coal have been mined. The coal bed is in the Eagle formation, dipping 21° E., and contains 48 inches of coal in two benches of about equal thickness, the upper bench being 22 inches and the lower bench 26 inches thick. The coal is a brownish-black subbituminous variety typical of the Eagle coals. When fresh it has a bright luster and well-developed joints and makes a desirable domestic fuel. If a market for the coal were accessible, this mine could be extended and a large amount of coal taken out.

Blake mine.—The Blake mine is about $2\frac{1}{2}$ miles above Meeteetse on the north side of Grey Bull River. It is now abandoned and caved to such an extent that a representative section could not be obtained. It consisted of a main entry about 150 feet long and several side entries. It is estimated that several thousand tons of coal have been taken from this mine since its opening in 1892.

Black Diamond mine.—During the summer of 1904 the Black Diamond or Woodruff mine was opened at the base of a small hill near the Cody-Meeteetse stage road, 3 miles northwest of Meeteetse. Since

that time it has been operated continuously. The coal bed is 42 inches thick, with no continuous partings, and it dips 20° E. The mine consists of one main gangway 400 feet long, two entries, and eight rooms, and is equipped with small coal cars which are brought to the surface by a cable wound on a drum driven by horsepower. One man is employed during the summer months and five in winter. It is estimated that this mine has produced 5,000 tons of coal, which has been sold to local ranchmen along Grey Bull Valley and in Meeteetse at \$2.25 per ton. The coal is a moderately hard black subbituminous variety which ignites readily and makes an excellent fuel. It slacks when exposed to the atmosphere, hence can not be stored in large quantities or for long periods of time. To the northwest along the strike the bed is exposed at intervals for more than a mile before it passes beneath the gravel-covered terrace which forms the eastern part of the Meeteetse Rim, but in the opposite direction it is covered by valley wash a short distance from the mine and is not exposed again between this place and Grey Bull River. At the river 44 inches of good coal is exposed. Farther southeast, beyond the river, the bed is thinner and can not be traced more than 2 miles.

Erskine mine.—The Erskine mine is situated on the south side of Grey Bull Valley, across the river from the Blake mine, in sec. 13, T. 48 N., R. 101 W. The mine is on a bed of Eagle coal which dips 12° NE. It consists of a main gangway 500 feet long, one entry 300 feet long, and a small room. About 4,500 tons of coal has been mined and sold for \$2.25 per ton at the mine. The mine is near the river, and within a short distance the dip of the strata carries the coal bed below water level, so that considerable difficulty is encountered in keeping the mine dry. The bed contains 5 feet of coal with a number of soft shale partings. A section measured at this mine is shown in No. 19, Pl. XI. The coal is a medium-hard black subbituminous variety, well suited for domestic purposes. As mined it includes a considerable quantity of dirt.

The workable coal in this bed seems to be restricted to the river valley and the area immediately north. Within a quarter of a mile to the south from the mine it thins below workable thickness and to the northwest a short distance beyond the Blake mine it is not minable.

Prospecting.—North of Grey Bull River prospecting has exposed a bed of workable coal on Meeteetse Creek near the mouth of Horse Creek above Gray's ranch and at the same horizon on Antelope Creek west of Meeteetse. Though not worked at present, it is expected that these beds will be developed in the future to supply a small amount of coal.

South of the river conditions are favorable for development at several places. Southeast of Meeteetse the Laramie (?) contains a coal

bed which has been prospected at the point marked No. 21 on Pl. XI. It continues southeastward for about $2\frac{1}{2}$ miles, then becomes too thin to be mined. The coal is subbituminous and suitable for domestic purposes, but the bed is included in soft shale, which renders mining difficult. The upper Buffalo Basin to the south is encircled by an outcrop of the Eagle sandstone, but at this place the formation does not contain workable coal beds. West of this basin, near the Iron Creek road, the Laramie (?) contains two beds of workable coal, one near the base of a steep northward-facing bluff and the other near its summit. A section measured at this point is shown in No. 22, Pl. XI. At present this region is difficult of access, but with increased demand for coal small mines could be operated.

The western part of the district contains extensive exposures of the Eagle sandstone which are coal bearing. A bed of workable coal extends along a steep westward-facing scarp on the east side of Wood River. The bed has been prospected, but no attempt at mining has been made. The Sunshine syncline previously discussed is encompassed by an outcrop of coal-bearing beds. In the southern half the beds attain workable thicknesses. The structure is unsymmetrical, the east limb dipping 40° to 50° and the west limb 10° to 15° . The trough is relatively narrow and the coal beds probably do not pass below workable depths. The coal occurs in two beds about 70 feet apart, only the lower one being of minable thickness. The thicker bed ranges from less than 30 inches in the north end of the syncline to $7\frac{1}{2}$ feet at one point near the south end. Sections measured at intervals about the syncline are shown in Nos. 28 to 35 on Pl. XI. The coal has a bright luster, is medium in hardness, and is relatively free from impurities. A mine has been opened in Sunshine Gulch and a small amount of coal taken out.

The Sunshine syncline is one of the best undeveloped areas in the western part of the Bighorn Basin. It contains a large tonnage of coal in a favorable attitude and of a quality which finds ready sale in the general market.

GRASS CREEK FIELD.

The Grass Creek field lies along the valley of Grass Creek, extending from Ilo post-office westward to the foot of the mountains and from Gooseberry Creek on the north to Cottonwood on the south. There are two coal-bearing formations—the Eagle, which is exposed in a zone encircling the Grass Creek anticline, and the Fort Union. The Eagle coal is workable along the northeast side of the anticline and at intervals on the west and southwest. It has been mined at Dickie No. 1 and prospected at Dickie No. 2 mine.

A bed of coal of workable thickness occurs on Left Hand Creek in T. 46 N., R. 100 W., but owing to the absence of good land surveys in

that township its exact location was not determined, and consequently its location as shown on Pl. XI is only relative.

Dickie mine No. 1.—Dickie mine No. 1 is on the north side of the Grass Creek anticline, in the NW. $\frac{1}{4}$ sec. 2, T. 46 N., R. 99 W., where the strata dip 19° N. The bed lies below a massive sandstone and contains 40 inches of coal in the lower bench. The mine consists of an entry about 100 feet long with one room opened to the west. About 200 tons of coal has been taken out to supply fuel to neighboring ranches. The physical properties of the coal are identical with those previously described from the Eagle sandstone.

Dickie mine No. 2.—Dickie mine No. 2, locally known as the O'Riley mine, is a small prospect in a gulch separating a small outlier from the main body, in the NE. $\frac{1}{4}$ sec. 14, T. 46 N., R. 99 W. The bed contains 7 feet 8 inches of coal in two benches. A section of the coal is shown by No. 47, Pl. XI. It is a subbituminous coal similar to that in Dickie mine No. 1. The bed at this prospect seems to be a local thickening of the upper bench. One-fourth of a mile to the west the bed is too thin to work, and at an equal distance along the strike to the south it has a diminished thickness and contains so many partings that it is not minable.

Prospecting.—All the coal beds in the Grass Creek field have been traced out by prospectors and opened at short intervals, and the limits of workable deposits have been determined. In the Mayfield syncline erosion has cut away the coal beds from the shallow trough until only remnants are left. Where the beds are uneroded, however, there seems to be sufficient capping to have prevented the alteration of the coals by atmospheric agencies. The syncline is cut transversely by Grass Creek, leaving a coal-bearing portion on either side. The coal occurs in three beds near the base of the Fort Union formation. One of the beds has a maximum thickness of 32 feet, the second of 15 feet, and the third of 6 feet. Sections of these beds are shown in Nos. 49 to 55; inclusive, Pl. XI, and an analysis of coal from the first bed is given on page 217. The coal is moderately hard, burns well, seems to stand exposure to the air, and as a domestic coal is highly satisfactory. To the unaided eye the coal is free from pyrite, but under a lens small irregular particles are visible. The area of the field is not great, but owing to the thickness of the beds it contains a large tonnage. The Mayfield district has been extensively prospected, but is wholly undeveloped, because there is no accessible market for the product.

On the north of the Grass Creek anticline there are opportunities for small mines. The beds have a workable thickness and a favorable dip. To their detriment, however, most of the exposures are high on the face of a steep escarpment, where it is difficult to construct and maintain roads.

GEBO FIELD.

The Gebo field extends from Bighorn River near Kirby westward between Meeyero and Owl creeks, and along Cottonwood Creek to the foothills of the mountains. The important mines in this field are the Eades, Price & Jones, Gebo, and Stein. The most extensive coal beds and the greatest number of producing mines are in the eastern part of the field. Beds of workable thickness underlie the Gebo syncline and outcrop from the west line of T. 44 N., R. 95 W., to the valley of Bighorn River.

Eades mine.—In the western part of the field the Eades mine is the only one of any size, though there are a number of prospects. This mine, located in sec. 33, T. 44 N., R. 96 W., is an opening on a bed of Eagle coal 45 inches thick and dipping 9°. The main entry is 150 feet long, with two rooms from which about 200 tons of coal have been removed. Sections of the coal and its workable extent along the strike are shown in No. 69, Pl. XI.

Price & Jones mine.—The Price & Jones mine, in the SW. $\frac{1}{4}$ sec. 22, T. 44 N., R. 95 W., in the east end of the Gebo syncline, is one of the oldest mines in the district. It was opened seven years ago and has been operated during the fall, winter, and early spring since that time. The mine workings consist of one main gangway, one entry, and three rooms, from which about 1,000 tons of coal have been taken and sold locally at \$2.50 per ton.

Gebo mines.—Pit No. 1, in the S. $\frac{1}{2}$ sec. 11, T. 44 N., R. 95 W., is only in an early stage of development, but is already the most extensive coal mine in northwestern Wyoming. From 20 to 65 men have been employed since the mine was opened in November, 1906. This mine is working on a coal bed 11 feet thick which dips 22°. The underground workings consist of one main gangway 1,200 feet long, one air course, and eight entries. About 8,000 tons of coal has been mined, but most of this is the product of development work previous to the construction of the Burlington Railroad. A spur track has just been completed to this mine and is being extended to mine No. 2, three-fourths of a mile to the southeast. A large tippie has been constructed and a complete set of hoisting and screening machinery is being put in place. Dwellings have been built for the miners and all provisions made for extensive operations. This mine is expected to produce 500 tons per day, which will be supplied to the railroads and shipped to various places in the Bighorn Basin and adjacent areas.

Development work has just begun on mine No. 2, where a main gangway has been driven for 240 feet, but no entries have been turned. The railroad is being extended to the mine, and complete equipment is to be installed.

Stein mine.—The Stein mine, 2 miles southeast of Gebo mine No. 1, in the SW. $\frac{1}{4}$ sec. 18, T. 44 N., R. 94 W., is, like the Gebo mines, being developed prior to the construction of railroad tracks. A main gangway has been driven for 200 feet and two entries have been opened. Six miners are employed, with an output of 20 tons per day. The small dump now in use and the horsepower haulage are to be replaced by a large tippie and a complete equipment of heavy machinery. This mine will probably be one of the large producers of the field. At present coal is hauled by wagon to Kirby station, and there loaded on cars. The selling price is \$2.50 per ton.

Prospecting.—The coal beds in the Gebo field have been examined along their outcrops by prospectors and openings made at short intervals. In the western part of the field the exposures usually occur in steep slopes where talus does not interfere with examination, hence prospect pits are unnecessary. Some mining has been done along Cottonwood Creek and in a syncline near the southern edge of the area, but at present these small mines are not operated. In this part of the field there are opportunities for small mines, but no beds thick enough to support extensive mining. In the eastern part the beds have been opened at many places and their thickness and extent along the outcrop determined. No drill records are available to show the condition of the beds down the dip, but it seems probable that they have about the same thickness as along the strike. Favorable conditions for the opening of mines exist near Bighorn River, west of the Gebo mines, and in the small syncline to the south.

CHARACTER OF THE COAL.

PHYSICAL PROPERTIES.

The coals of the western side of Bighorn Basin are subbituminous. The Fort Union and Laramie (?) coals are black and the Eagle brownish black. The Eagle, however, and to a less extent the Laramie (?) coals contain thin lusterless layers alternating with bright bands, giving to the vertical faces of the bed a faintly banded appearance. On the other hand, the Fort Union coal has a uniform texture and is not banded. Jointing is either indistinct or absent. The Eagle coal shows a moderate tendency to break along bedding planes and less regularly in perpendicular planes, but the Fort Union coal is almost devoid of regular joints. Specimens from the various beds are medium in hardness and show a tendency toward a small conchoidal fracture, and in some samples of Fort Union coal there is a peculiar pitted structure which has been designated by English writers as "bird's-eye." Some of the lower beds contain small accretions of light-brown resin similar to the resin balls in the coal mines

at Red Lodge, Mont., but in smaller nodules and more widely scattered than in either of the coals noted. The physical properties of the beds in the higher strata resemble those of the coal at Red Lodge and Bear Creek, Mont., and the lower coal is similar to that at Bridger. To the unaided eye the coal appears free from pyrite, but under a lens small irregular particles are visible.

CHEMICAL PROPERTIES.

The composition of the coal is shown in the accompanying table. Samples for analysis were taken at the various mines and prospects in the field according to the method described by M. R. Campbell on pages 12-13 of this volume. Analyses were made under the direction of F. M. Stanton, of the United States Geological Survey.

The table shows both proximate and ultimate analyses of the coal as received at the laboratory and after air drying. The analysis of the sample as received indicates the condition of the coal as it comes from the mine; that of the air-dried sample denotes approximately the state of the coal as it is burned. In comparisons, therefore, the analysis of the air-dried sample should be taken.

Analyses of coal samples from the southwest side of the Bighorn Basin, Wyoming.

[F. M. Stanton, chemist in charge.]

Name of field.....		Cody.				Meeteetse.			Grass Creek.	Gebo.		
Laboratory No.....		a 5763.	a 5766.	b 5762.	b 5767.	b 5768.	b 5764.	b 5769.	a 5770.	b 5787.	b 5788.	c 5765.
Sample as received:												
Prox.	Moisture.....	13.77	17.29	13.43	15.04	17.67	16.12	15.04	12.84	17.04	16.11	12.08
	Volatile matter.....	35.03	31.33	35.16	31.87	27.28	35.12	32.49	33.96	35.53	32.96	32.58
	Fixed carbon.....	39.31	45.89	42.86	38.39	47.46	40.78	41.64	48.15	45.10	48.09	49.23
	Ash.....	11.89	5.49	8.55	14.70	7.59	7.98	10.83	5.05	2.33	2.84	6.11
Ult.	Sulphur.....	.64	.35	.44	.76	.17	.53	1.07	.39	.37	.50	.91
	Hydrogen.....	5.42	5.64	5.92	5.49	5.35	5.91	5.67	5.92	5.96	5.97	5.42
	Carbon.....	52.84	59.15	58.42	52.42	57.08	54.12	55.43	63.68	62.22	62.50	63.76
	Nitrogen.....	1.00	.85	1.05	.97	.84	.92	1.10	.80	1.11	1.04	.99
Oxygen.....		28.21	28.52	25.62	25.66	28.97	30.54	25.90	24.16	28.01	27.15	22.81
Calories.....		5,148	5,586	5,638	5,150	5,382	5,179	5,514	6,248	6,106	6,228	6,251
British thermal units.....		9,266	10,055	10,148	9,270	9,688	9,322	9,925	11,246	10,991	11,211	11,252
Loss of moisture on air drying.....												
		4.80	5.70	5.00	4.60	6.30	5.50	4.40	2.90	5.30	5.40	3.00
Air-dried sample:												
Prox.	Moisture.....	9.42	12.29	8.87	10.94	12.13	11.24	11.13	10.24	12.40	11.32	9.36
	Volatile matter.....	36.80	33.22	37.01	33.41	29.12	37.16	33.98	34.97	37.52	34.84	33.59
	Fixed carbon.....	41.29	48.67	45.12	40.24	50.65	43.15	43.56	49.59	47.62	50.84	50.75
	Ash.....	12.49	5.82	9.00	15.41	8.10	8.45	11.33	5.20	2.46	3.00	6.30
Ult.	Sulphur.....	.67	.37	.46	.80	.18	.56	1.12	.40	.39	.53	.94
	Hydrogen.....	5.14	5.31	5.64	5.22	4.96	5.61	5.42	5.77	5.67	5.68	5.25
	Carbon.....	55.50	62.73	61.50	54.95	60.92	57.27	57.98	65.58	65.70	66.07	65.73
	Nitrogen.....	1.05	.90	1.11	1.01	.90	.97	1.15	.83	1.17	1.10	1.02
Oxygen.....		25.15	24.87	22.29	22.61	24.94	27.14	23.00	22.22	24.61	23.62	20.76
Calories.....		5,408	5,924	5,935	5,398	5,744	5,480	5,768	6,435	6,448	6,584	6,444
British thermal units.....		9,733	10,662	10,682	9,717	10,339	9,865	10,382	11,582	11,606	11,851	11,600

a Sampled by E. G. Woodruff. b Sampled by R. L. Nelson. c Sampled by E. L. De Golyer.

According to the classification of coal adopted by the United States Geological Survey, these coals are of the high-grade subbituminous

variety, which closely approach the bituminous class. The coal usually cleaves in small blocks and at some places breaks into prisms, but weathering generally develops a platy structure along the bedding planes. This coal does not stock well, and is therefore placed below the bituminous class, though in heat value it approaches some of the bituminous coals of the Mississippi Valley.

The heat value of three of the coals given in the above table falls below 10,000 British thermal units. This low heat value is probably due to the high ash or moisture content and not to the quality of the coal, and therefore these three coals should be classed like the others. The coal ignites readily and burns freely. It gives a quick but not a long-continued heat and is adapted to general use, especially for domestic purposes. Analyses of coals from adjacent regions, by which comparison may be made, are given by other writers in this volume.

MARKET.

The market for the Bighorn Basin coal fields is and probably will remain in the railroads of the region and the agricultural areas where irrigation is carried on. At present large tracts of land are being irrigated in the Bighorn Basin, and the area of irrigation is rapidly extending. The United States Reclamation Service is now engaged on an extensive project at Cody which will bring a large tract of land under cultivation by people who will demand fuel for many months each year. Private companies are planning to construct extensive irrigation works, which are attracting settlers. These various settlements will increase the demand for domestic fuel, which will probably be supplied from the mines in the field. The railroads of the basin will probably draw on the mines for a constant supply. There are no large cities with extensive manufacturing plants in the area, nor is there promise of any being established in the immediate future. Any estimate of the production of the fields at the present time can not be fairly representative, for the southeastern field is rapidly developing.

FUTURE DEVELOPMENT.

These coal fields have a very promising future. During the fall of 1907 the Gebo field was entered by the southern extension of the Burlington Railroad to Kirby station, where the mines of the Gebo district are being rapidly developed. A branch of the same railway reaches Cody, but in that vicinity there are no coal beds which promise extensive development. The Grass Creek and Meeteetse are two very promising fields which remain without railway facilities, hence

they are not extensively developed. A survey has been made for a railway to extend from Basin, on Bighorn River, up Grey Bull River past Meeteetse to the junction of Wood River, thence up Wood River to Kirwin, in the mountains, thus in its course crossing the Meeteetse field. The Grass Creek field could be entered by a line of railroad extending from a point near Kirby station up Meeyero and Grass creeks to the Grass Creek basin. Neither of these suggested lines is impossible and both of them seem to promise easy construction.

THE EASTERN PART OF THE GREAT DIVIDE BASIN COAL FIELD, WYOMING.^a

By E. EGGLESTON SMITH.

INTRODUCTION.

The Great Divide Basin coal field is situated along and north of the Union Pacific Railroad in south-central Wyoming, and embraces portions of the northeast end of Sweetwater County, the northwest end of Carbon County, and the southeast corner of Fremont County. The portion^b of the basin covered by this report extends from Rawlins westward along the Union Pacific Railroad to Tipton and from the railroad northward to the Green Mountains, Muddy Creek Gap, and the Ferris Mountains, and includes Tps. 21 to 28 N., Rs. 88 to 92 W.; Tps. 21 to 25 N., Rs. 93 to 96 W.; and portions of T. 20 N., Rs. 90 to 96 W.

A detailed reconnaissance survey was made of this region. Geologic and topographic sketch maps were constructed on the scale of 2 inches to the mile. As the primary object of the survey was to classify the coal land, the horizontal control was based entirely on Land Office subdivisions. Land lines were paced at intervals of one-half mile to 2 miles, depending on the character of the relief, the distribution of the coal outcrops, and the complexity of the geology. All geologic and topographic data were tied to the nearest known Government corners on the lines thus run. A detailed topographic base map on the scale of 1 inch to the mile is now being constructed from the field sheets and will be included in the final report. This map will show the geologic structure and the distribution of the coal-bearing formations, the outcrops of the principal coal beds, the location of coal mines and prospects, and the surface exposures where sections of coal beds were measured.

In preparing the map (Pl. XII) accompanying this report the lengths of the land lines as given on the plats of the original Land Office surveys were accepted as correct and were plotted by so

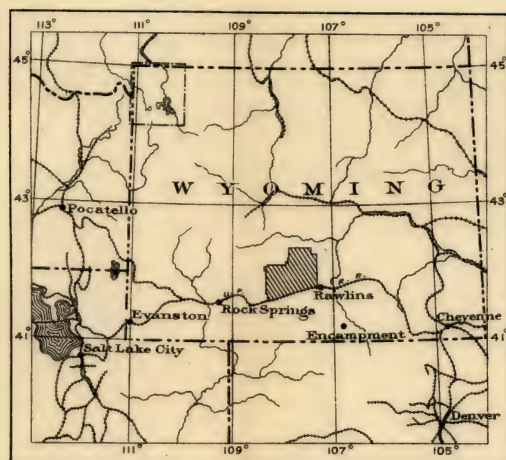
^a This paper is a preliminary report of field work carried on by the writer, assisted by W. B. Heroy, E. B. Hopkins, William Mulholland, and V. H. Barnett, during the summer of 1907. A final report is in course of preparation and will be published as a separate bulletin.

^b For a description of the other portions of the Great Divide Basin, see reports by Max W. Ball and Alfred R. Schultz (pp. 243 and 256).

LEGEND

of Coal-bearing formations

- Wasatch
- Undifferentiated Tertiary
- Laramie
- Mesaverde
- Coal outcrops
(Solid lines where visible
and broken where covered.)
- Coal mine and prospect
- Dip and strike
- Wagon road



INDEX MAP

Line 15 miles from railroad

North line of N.P.R.R. land grant

Divide between Atlantic and Great Divide Basin drainage

R. 96 W.

R. 95 W.

R. 94 W.

R. 93 W.

R. 92 W.

R. 91 W.

R. 90 W.

R. 89 W.

R. 88 W.

T. 26 N.
T. 27 N.

T. 26 N.

T. 24 N.

T. 23 N.

T. 22 N.

T. 21 N.

T. 20 N.

T. 19 N.

R. 93 W.

R. 92 W.

R. 91 W.

R. 90 W.

R. 89 W.

R. 88 W.

Scale

10 miles

MAP OF THE EASTERN PART OF THE GREAT DIVIDE BASIN COAL FIELD, WYOMING

By E. Eggleston Smith, W. B. Heroy and E. B. Hopkins

balancing the recorded distances about two perpendicular right lines intersecting near the center of the map that the distortions due to convergence of meridians and errors of surveying are distributed equally over the sheet. As a result of this balanced plotting of distances rather than directions the length of the sides of any given township or section on Pl. XII agrees with that given on the Land Office plat, but the shape of the township or section may be different from the shape shown on that plat or from the true shape. Because of this method of construction Pl. XII does not exactly agree in the shape of the land subdivisions in the parts where it coincides with the maps of the Little Snake River coal field (Pl. XIII), of the northern part of the Rock Springs coal field (Pl. XIV), and of the east-central Carbon County fields.^a

TOPOGRAPHY AND DRAINAGE.

Most of the topography of this area is simple and very favorable to economic development of the coal beds. At no place does the coal reach an altitude greater than 7,400 feet. About five-sixths of the total area, comprising the entire central, western, and southern parts, and a small fraction of the east-central part, is a region of very low relief. It is characterized by broad flats containing small alkaline lakes and scattered silt and sand dunes; low, flat-topped hills, many of which are capped by gravel; low, abrupt escarpments at the edges of the flat-topped hills; broad, gently sloping outwash plains; and relatively low, parallel ridges formed by the outcrops of highly inclined, rather soft beds of sandstone. The last-mentioned feature is peculiar to a narrow belt running a little west of north from Solon, on the Union Pacific Railroad, to Lost Soldier, in T. 26 N., R. 90 W., and coinciding with the outcrops of the upper members of the Cretaceous system.

In the remaining sixth of the area the relief is much greater, the altitude ranging from 6,450 feet above sea level near Boundary Lake, in T. 23 N., R. 88 W., to 9,200 feet at the top of Whisky Peak, in T. 27 N., R. 90 W. This part of the basin may be divided into four districts, each having its own topographic characteristics. The Rawlins Hills, in Tps. 21 to 24 N., R. 88 W., form one district characterized by abrupt scarp faces and long dip slopes. The Ferris Mountains, in T. 26 N., R. 88 W., T. 27 N., Rs. 88 and 89 W., and T. 28 N., R. 89 W., form another district resembling that of the Rawlins Hills, but with a much greater range of elevation. The Green Mountains, of which Whisky Peak forms the east end, compose the third district. They are situated in Tps. 27 and 28 N., Rs. 90 to 92 W. This district is characterized by a broad, plateau-like summit with high, irregular, systemless spurs and deep valleys running out

^a Veatch, A. C., Bull. U. S. Geol. Survey No. 316, 1906, Pl. XIV.

to the north and south. The relief on the north side of the mountains is much greater and more rugged than on the south side. Extending southeastward from a point near the center of Green Mountains to the valley of Separation Creek, in T. 23 N., R. 89 W., is a prominent escarpment which makes up the fourth district. The face of the escarpment is somewhat irregular and is cut in several places by large valleys heading behind the main crest. The top of the escarpment decreases in altitude gradually toward the south. From the crest low hills and broad undulating plains slope off gently toward the southwest, where they merge into the flats of the Great Divide Basin.

The general character of the drainage, the absence of permanent streams, and the highly alkaline character of the water of the lakes of this area are unfavorable to economic development of the coals. All but about 300 square miles of the region covered by this survey has no outward drainage. The Continental Divide to the south of this field follows the crest of the Sierra Madre and the Savery Plateau nearly to the headwaters of Separation and Muddy creeks, in sec. 7, T. 18 N., R. 89 W. Here the main divide is replaced by two low divides which separate the interior drainage from the Atlantic drainage on the east and north and from the Pacific drainage on the south and west. The eastern divide trends east of north, crossing the Union Pacific Railroad near Ferris, thence passing across the center of the Rawlins Hills to a point near North Platte River, in T. 22 N., R. 86 W., thence north along the Haystack Hills nearly to the eastern summit of the Ferris Mountains, thence nearly westward to South Pass, touching the crests of the Green Mountains, Crooks Mountain, and Antelope Hills only for short distances and making wide detours to the southward around the drainage basins of Muddy, Crooks and Alkali creeks. The western divide runs nearly westward to Robinson, on the Union Pacific Railroad, following for a part of the distance the crest of the Laney Rim, thence running northwestward to the vicinity of Steamboat Mountain and South Pass. At South Pass the two low divides reunite in one main divide which continues northward along the crest of the Wind River Mountains. These low divides inclose a basin area of approximately 4,200 square miles.

All the streams of the basin are intermittent, flowing only during the melting of snows in the spring. They flow into broad depressions, forming shallow lakes, many of which dry up during the summer. Six large depressions receive most of the drainage. They are as follows, enumerated from east to west: Separation flats, in Tps. 23 and 24 N., Rs. 87 and 88 W., and in Tps. 20 to 23 N., Rs. 89 and 90 W.; Lost Soldier flats, in T. 26 N., R. 89 W.; Dry Lake flats, which extend westward in T. 22 N. through Rs. 91 to 94 W.; Chain Lake flats, which extend westward through T. 23 N., Rs. 90 to 94 W.;

Lost Creek flats, in Tps. 23 and 24 N., Rs. 94 and 95 W.; and Red Desert flats, which extend northwestward from the Union Pacific Railroad at Red Desert through Tps. 20 to 25 N. and Rs. 95 to 97 W. Most of the large and many of the small depressions are occupied by small, shallow alkaline lakes into which there is no distinct drainage. The lakes lie at or just below the mean ground-water level, and are supplied by ground water, being much larger during wet than during dry seasons.

All of the remaining area—300 square miles—lies on the Atlantic side of the watershed. About 36 square miles in Tps. 21 and 22 N., R. 88 W., near Rawlins, drains eastward into North Platte River. The remainder, in T. 26 N., Rs. 88 and 89 W., and Tps. 27 and 28 N., Rs. 88 to 92 W., drains into Sweetwater River. The only permanent streams in the area are situated in the latter region.

GEOLOGY.

STRATIGRAPHY.

The coal-bearing rocks of the area here described are of Upper Cretaceous and Tertiary ages. They consist of the Colorado, Montana, Laramie, undifferentiated Tertiary, and Wasatch formations. Of these, only the last four contain workable coal beds. Thin beds of coal occur in the basal portion of the Colorado, but at no place within the area treated do they reach minable thickness. The coal-bearing formations show considerable change in character from the southern to the northern edge of the field. Those of the Cretaceous system thin rapidly toward the north and the outcrops of the beds of the undifferentiated Tertiary become more and more narrow, owing to the overlap of Wasatch conglomerate. The accompanying section (pp. 224-225) shows the thickness and general characteristics of the coal-bearing formations near the Union Pacific Railroad and in the gap between Whisky Peak and the Ferris Mountains.

Section of the Cretaceous and Tertiary rocks of the Great Divide Basin coal field, Wyoming.

Syst. tem.	Group	Formation	Thickness in feet.		General characteristics.	Economic resources.
			South end of field.	North end of field.		
Tertiary.	Undifferentiated Tertiary. ^a	Wasatch.	900 ±	1,800 ±	In the southern part of the area it is composed of massive white and yellowish-brown soft sandstones alternating with layers of drab to black carbonaceous shale. The sandstone members harden locally and weather into forms resembling large concretions. The basal portion is also concretionary and contains small granite pebbles. In the northern part of the field it consists entirely of white conglomerate containing decomposed granite boulders up to 6 feet in diameter in the upper portion, and of coarse-grained white sandstone containing scattered boulders of granite and sedimentary rocks in lower portion.	Coal bearing in southern and western portions of the field. Contains numerous thin beds of lignite and impure subbituminous coal; several workable beds of low-grade subbituminous coal near the center.
		Unconformity			Alternating layers of soft yellowish-brown and white sandstones and drab, brown, and black shales. The middle portion consists of soft shale and sandstone and is not exposed in this area. Massive white sandstone at the base is conglomeratic and contains pebbles of Paleozoic rocks. At the north end of the field only the lower part of the formation is exposed. The proportion of shale is much greater than at the south end. The basal portion contains conglomeratic layers with Cretaceous pebbles up to 8 inches in diameter.	Coal bearing. Several beds of workable coal occur in the upper portion near Cherokee, and in the lower portion near Knobs. Not coal bearing in northern part of the field.
		(?)	7,980 ±	2,000	Alternating layers of soft drab, brown, and black shales and thin strata of dark, rusty-brown resistant sandstone. Sandstone is increasingly conglomeratic toward the top. Shales in northern portion erode into badland forms.	
	(?)	Unconformity	800 ±	1,800	Alternating layers of yellowish-brown and white massive sandstones, thin brown sandstone, and drab, brown, and black shales. Sandstones are very resistant in southern portion. At north end the sandstones in the basal part are more resistant than those in the upper part, and constitute prominent topographic features.	In southern part of the field it is prolifically coal bearing throughout. The coal beds are numerous, but none of them are very thick. In northern part of the field the upper portion is prolifically coal bearing, and the lower portion is slightly so.
	(?)	Laramie. ^b	3,900 ±	1,050		

Cretaceous.	Montana.	Lewis shale.	1,520±	520	In southern part of the area it consists of very dark drab shale with considerable gypsum and several thin layers of rusty sandstone. In the northern part of the area it consists of drab shale and soft yellowish-brown sandstone containing some thin layers of gypsum. Produces a region of low relief.	Coal bearing above and in base of upper massive sandstone and at top of lower massive sandstone. The two upper coal-bearing zones contain workable coal. The lower zone contains coal too thin to be mined. Coal has been taken from middle zone near Ferris. Basal member may be of economic value as building stone. In northern part of field the beds are thin and poorly exposed.
		Mesaverde.	3,600±	2,000±	Near the top and at the base are two massive white sandstones which are resistant and form two prominent ridges or hogbacks. Between them is a soft brown sandstone interbedded with drab to brown shale.	
		(c)	5,000±	4,000±	Upper portion is exposed only at south end of field and consists of soft brown shaly sandstone interbedded with drab to brown shale. Lower portion consists of very dark drab calcareous shale, containing numerous thin, soft brown sandstones near the top. Produces areas of low relief.	
		Frontier sandstone member.	900±	500	Three massive yellowish-brown sandstones with dark shale between, containing numerous concretions. Upper sandstone is slightly conglomeratic.	Sandstones may be of economic value as building material.
Colorado.		Mowry shale member.	700±	1,000	Compact gray and black shales which break with conchoidal fracture and contain abundant fish scales.	May be of economic value in the manufacture of Portland cement.
			30±	20±	Massive yellowish-brown to pink sandstone resembling Dakota.	May be of value as building material.
			100±	60±	Black shale which breaks with conchoidal fracture.	Contains very thin beds of impure coal along south base of Ferris Mountain.
		Dakota sandstone.	100-150	100-175	Massive yellowish-brown to pink sandstone, containing small chert pebbles near base. Locally quartzitic.	May be of value as building material.

^a The fossil evidence from this group is conflicting and the age of the group can not be decided until further paleontologic work is done.

^b Marine Cretaceous (upper Montana) species were obtained about 500 feet above the base of this formation in sec. 1, T. 21 N., R. 89 W., and at the base in sec. 26, T. 26 N., R. 90 W. They may probably be found at various places in the lower portion, and therefore no definite formation line can be drawn on paleontologic evidence. The base of the sandstones has been used in mapping the formation because it is the only line which is marked lithologically.

^c This formation is equivalent to the Niobrara and the basal shale portion of the Montana. A local name will probably be applied to it.

STRUCTURE.

A line trending 20° west of north from Knobs, on the Union Pacific Railroad, divides the region into two structural units. The part to the west is a broad, flat synclinal basin and is filled with nearly horizontal Tertiary strata. Beds of undifferentiated Tertiary outcrop in small isolated patches across the southeastern corner of this area, with a strike of about $N. 30^{\circ} E.$ and a dip of 15° to $18^{\circ} NW.$ which within a short distance flattens to between 5° and 7° . The coal beds in this part are very nearly horizontal and can be easily worked some distance back from the outcrop, or they may be reached by shafts at moderate depths. In the area east of the line mentioned above the formations are more or less highly tilted. From the Union Pacific Railroad between Ferris and Knobs the coal-bearing formations strike northwestward to a point near Lost Soldier, in T. 26 N., R. 90 W., having a dip of 25° to $80^{\circ} W.$; thence they swing eastward, dipping to the north under Whisky Peak. The lower formations continue southeastward in a narrow syncline parallel to and about 6 miles from the crest of the Ferris Mountains, until they disappear beneath sand dunes in T. 26 N., R. 88 W. The upper formations turn around a low anticline in the large syncline and join the north limb of the syncline, whence they continue northwestward until they disappear under the terraces and against the granite of the Sweet-water Valley. Throughout this area the coal beds are highly inclined and can in only a few places be developed more than a mile from the outcrop. Whisky Peak, the Green Mountains, and the ridge trending southeastward from the vicinity of Lost Soldier are composed of massive Wasatch conglomerate capped by waterworn granite boulders, and these rocks conceal the coal-bearing formations over a large area.

THE COAL.

COAL-BEARING FORMATIONS.

COLORADO GROUP.

The oldest beds containing coal in this region are probably of lower Colorado (Benton) age. They are the shale and sandstone members which lie between the heavy Dakota sandstone and conglomerate and the overlying Mowry shale member. Although no fossils have been found in these beds, from their lithologic resemblance to the overlying rocks they have been tentatively referred to the lower portion of the Benton. They contain coal in a few places along the southern flank of the Ferris Mountains. The beds are thin and the coal is very impure; consequently they are of no economic value, and are therefore not shown on the accompanying map. The Frontier sandstone member, which contains the high-grade Kemmerer coals of western Wyoming, was not observed to be coal bearing in this region.

MESAVERDE FORMATION.

The best coal beds of this region occur in the Mesaverde formation. This is characterized throughout the region by two prominent ridges of rather resistant, massive white sandstone, between which are alternating beds of soft brown sandstone and carbonaceous shale which weather down and form a pronounced depression except where covered by gravel in the northern part. The coal occurs in three zones—one near the middle of the formation, immediately overlying the lower heavy sandstone member; another in the base of the upper sandstone member, and a third at the top of the formation.

In the lower coal zone there are four to six irregular beds of impure coal. The exposures are very poor, and where the beds were seen they were too thin to be worked profitably at the present time. The exposures of the middle coal zone are also very poor. In the portion of the field between Lost Soldier and Separation Creek there are several thin beds, but they are of no economic value. South of Separation Creek the beds appear to thicken toward the south and at the Union Pacific Railroad near Ferris, in sec. 22, T. 21 N., R. 88 W., the coal bed exposed in an abandoned mine has a thickness of 8 feet 4 inches. This is the only place within the field where Mesaverde coal has been mined. South of the railroad, in sec. 36, T. 21 N., R. 88 W., coal has been taken from the same zone at the old Dillon mine.^a In the upper coal zone there are four or more thin beds of coal. They have not been mined within the field, but, according to Veatch,^b near the Seminole Mountains, in sec. 23, T. 25 N., R. 86 W., at the Fieldhouse opening, some coal has been taken from one of these beds for local use. Three sections of coal beds of the middle and upper zones are given in the following table:

Sections of coal beds in Mesaverde formation.

No. on Pl. XII.	Location.			Section of coal bed.		Remarks.
	Sec.	T.	R.			
1	SE. $\frac{1}{4}$ SE. $\frac{1}{4}$.	22	21	88	Shale.	Abandoned coal mine. Opened 75 feet.
					Coal.....	
					Shale.....	
					Coal.....	
					Shale.....	
					Coal.....	
					Shale.....	
2	SW. $\frac{1}{4}$ SE. $\frac{1}{4}$.	22	21	88	Sandstone.	Surface prospect.
					Coal, poor.....	
3	SW. $\frac{1}{4}$ NW. $\frac{1}{4}$.	4	24	89	Shale.....	Surface prospect.
					Coal, impure.....	
					Shale.....	
					Coal, impure.....	
					Shale.....	
					Coal, impure.....	
					Shale.....	
					6 2	

^a Veatch, A. C., Coal fields of east-central Carbon County, Wyo.: Bull. U. S. Geol. Survey No. 316, 1907, p. 248. Ball, M. W., The western portion of the Little Snake River coal field, Wyoming, pp. 243-255 of this volume.

^b Loc. cit.

LARAMIE FORMATION.

The Laramie formation is composed of soft carbonaceous shale and white to brown sandstone and appears as a prominent ridge throughout most of the field. It is separated from the Mesaverde by the soft, calcareous shale of the Lewis. The basal portion of the Laramie as mapped contains marine invertebrates which are referred to upper Montana (Lewis) age. This condition is common throughout much of southern Wyoming and northern Colorado (see pp. 224-225), and has led to the inclusion in the Laramie of these massive beds on the ground of their lithologic similarity to the other part of that formation.

The Laramie formation is prolifically coal bearing throughout. In secs. 29 and 30, T. 25 N., R. 89 W., about 1,800 feet of strata contain a total thickness of about 54 feet of coal, nearly 28 feet of which is of workable thickness. The following section shows the number and thickness of the beds and their relative positions:

Section of a part of the Laramie formation in secs. 29 and 30, T. 25 N., R. 89 W.

	Ft.	in.
Sandstone, gray, and drab shale.....	45	
Coal.....	1	10
Sandstone and shale, brown to drab.....	58	10
Coal.....	1	3
Shale and sandstone, brown.....	84	3
Coal, good.....	2	3
Shale, brown and drab.....	18	9
Coal, good.....	4	1
Shale, drab.....	5	
Coal.....	1	7
Shale and sandstone, brown and drab.....	35	3
Coal.....		2
Shale, brown, carbonaceous.....	78	
Coal.....	1	3
Shale.....		4
Coal.....		3
Sandstone and shale, brown.....	29	3
Coal.....		9
Shale and sandstone.....	46	6
Coal.....	2	4
Shale and sandstone, alternating.....	76	6
Coal.....	1	6
Shale and sandstone, brown.....	23	8
Coal.....		6
Shale and shaly sandstone.....	75	1
Coal.....		2
Sandstone and shale, carbonaceous and brown.....	123	7
Coal.....		10
Shale and sandstone.....	65	5
Coal.....	1	4
Shale, brown and drab.....	9	9
Coal.....	1	3

	Ft.	in.
Shale.....	7	6
Coal.....		3
Shale and sandstone.....	9	2
Coal.....		6
Sandstone, yellow to brown.....	12	4
Coal.....		5
Sandstone, soft, with some shale.....	40	8
Coal.....	2	4
Shale.....	2	5
Coal.....	3	
Shale.....	6	
Coal.....	3	
Shale.....	3	11
Coal.....		8
Sandstone and shale.....	11	3
Coal.....	1	8
Sandstone with drab shale.....	55	2
Coal.....	7	6
Shale and sandstone.....	75	
Coal.....		10
Sandstone and brown shale.....	40	2
Coal.....		2
Sandstone, gray.....	40	8
Coal.....	4	3
Shale, brown.....	3	4
Coal.....	1	2
Shale, brown and drab.....	11	7
Coal.....	1	2
Shale, black and drab.....	2	8
Coal.....		3
Shale and sandstone.....	20	3
Covered, occasional sandstone outcrop.....	300	
Coal.....	1	6
Sandstone and drab shale.....	213	5
Coal, bony.....		10
Shale and sandstone.....	37	
Coal.....	1	1
Shale, black, and gray sandstone.....	99	

1, 825 11

The general character and thickness of the coal beds of the Laramie formation are shown in the following measured sections:

Sections of coal beds in Laramie formation.

No. on Pl. XII.	Location.				Section of coal bed.	Remarks.
	Sec.		T.	R.		
4	NE. 4.	12	21	89	Shale..... <i>Ft. in</i> 15	Surface exposure.
					Coal, good..... 6 3	
					Shale..... 3	
					24 3	

Sections of coal beds in Laramie formation—Continued.

No. on Pl. XII.	Location.			Section of coal bed.	Remarks.
	Sec.	T.	R.		
5	NE. $\frac{1}{4}$ NE. $\frac{1}{4}$.	12	21	89	Surface exposure.
6	NE. $\frac{1}{4}$ NW. $\frac{1}{4}$.	1	21	89	Surface exposure.
7	NW. $\frac{1}{4}$ NE. $\frac{1}{4}$.	1	21	89	Surface exposure.
8	NW. $\frac{1}{4}$ NE. $\frac{1}{4}$.	1	21	89	Surface exposure.
9	SE. $\frac{1}{4}$ SW. $\frac{1}{4}$.	36	22	89	Surface exposure.
10	NE. $\frac{1}{4}$ NW. $\frac{1}{4}$.	3	22	89	Surface exposure.
11	NW. $\frac{1}{4}$ NW. $\frac{1}{4}$.	27	23	89	Surface exposure.
12	SE. $\frac{1}{4}$ NE. $\frac{1}{4}$.	30	25	89	Surface exposure.
13	SE. $\frac{1}{4}$ NE. $\frac{1}{4}$.	30	25	89	Surface exposure.
14	NE. $\frac{1}{4}$ NE. $\frac{1}{4}$.	30	25	89	Surface exposure.
15	NE. $\frac{1}{4}$ NE. $\frac{1}{4}$.	30	25	89	Surface exposure.

Sections of coal beds in Laramie formation—Continued.

No. on Pl. XII.	Location.				Section of coal bed.	Remarks.
	Sec.	T.	R.			
16	NW. $\frac{1}{4}$ NW. $\frac{1}{4}$.	29	25	89	Shale. Coal, good..... 7 Coal (?)..... 3 Shale. 10	Surface prospect.
17	NW. $\frac{1}{4}$ NW. $\frac{1}{4}$.	29	25	89	Sandstone. Coal..... 5 7 Shale..... 4 6 Coal..... 1 6 11 7	Surface exposure.
18	SE. $\frac{1}{4}$ NW. $\frac{1}{4}$.	18	25	89	Sandstone..... 4 Coal..... 3 Shale..... 1 10 Coal..... 5 Sandstone..... 8 Coal, good..... 6 10 Shale..... 7 14 7	Surface prospect.
19	SE. $\frac{1}{4}$ NW. $\frac{1}{4}$.	18	25	89	Sandstone. Coal..... 12 Shale and sandstone. 78 11 Coal, good..... 2 Shale..... 1 Coal, good..... 4 2 Shale..... 8 97 10	Surface prospect.
20	NE. $\frac{1}{4}$ NW. $\frac{1}{4}$.	31	26	89	Shale..... 1 Coal..... 2 Shale..... 15 Coal..... 6 24	Surface exposure.
21	SE. $\frac{1}{4}$ NW. $\frac{1}{4}$.	36	26	90	Sandstone. Coal..... 8 Shale..... 8 Coal..... 3 4 Shale..... 1 6 6 2	Surface exposure.
22	SE. $\frac{1}{4}$ NW. $\frac{1}{4}$.	36	26	90	Sandstone..... 6 Coal..... 11+ Shale..... 3+ 20+	Surface prospect.
23	NE. $\frac{1}{4}$ SE. $\frac{1}{4}$.	27	26	90	Shale and sandstone..... 63 Coal, good..... 10 5 Shale..... 20 93 5	Surface exposure.
24	NE. $\frac{1}{4}$ SE. $\frac{1}{4}$.	27	26	90	Shale..... 2 Coal, good..... 2 2 Shale..... 10 Coal..... 1 3 Shale..... 10 16 3	Surface exposure.
25	NE. $\frac{1}{4}$ SE. $\frac{1}{4}$.	27	26	90	Shale, carbonaceous..... 2 Coal..... 1 5 Shale, carbonaceous..... 8 6 Coal, good..... 9 1 Shale..... 5 3 26 3	Surface exposure.
26	NE. $\frac{1}{4}$ NW. $\frac{1}{4}$.	16	26	90	Sandstone. Coal..... 12 Shale.	Abandoned mine near Lost Soldier.

Sections of coal beds in Laramie formation—Continued.

No. on Pl. XII.	Location.			Section of coal bed.	Remarks.
	Sec.	T.	R.		
27	SW. $\frac{1}{4}$ NE. $\frac{1}{4}$.	4	26 90	<i>Ft. in.</i> Shale..... 1 Coal..... 4 6 Shale..... 2 Coal..... 1 Shale..... 6 8	Abandoned mine.
28	NE. $\frac{1}{4}$ SW. $\frac{1}{4}$.	33	27 90	Shale..... Coal..... 6 Shale..... 2 6 Coal..... 2 10 6	Surface exposure.
29	SE. $\frac{1}{4}$ SE. $\frac{1}{4}$.	20	27 89	Shale..... Coal..... 3 4 Shale..... 3 4 Coal..... 7 Shale..... 2 Coal..... 10 Shale..... 8 3	Surface exposure.
30	SW $\frac{1}{4}$ NE. $\frac{1}{4}$.	17	27 89	Shale..... 6 Coal, impure..... 1 Shale..... 6 Coal..... 8 4 Shale..... 21 4	Surface prospect.
31	NE. $\frac{1}{4}$ SE. $\frac{1}{4}$.	17	27 89	Coal..... 10	Surface exposure.
32	NE. $\frac{1}{4}$ NW. $\frac{1}{4}$.	17	27 89	Coal..... 8 4	Surface exposure.
33	NE. $\frac{1}{4}$ NW. $\frac{1}{4}$.	17	27 89	Coal..... 7	Surface exposure.
34	NE. $\frac{1}{4}$ NW. $\frac{1}{4}$.	17	27 89	Shale..... Coal..... 7 9	Surface exposure.
35	SW. $\frac{1}{4}$ NW. $\frac{1}{4}$.	8	27 89	Sandstone. Shale..... 1 2 Coal..... 12 Sandstone..... 13 2	Abandoned coal minè. Opened 96 feet. Down dip of 25°.
36	SW. $\frac{1}{4}$ NW. $\frac{1}{4}$.	8	27 89	Coal..... 6±	Mine abandoned and caved.
37	SW. $\frac{1}{4}$ SE. $\frac{1}{4}$.	6	27 89	Sandstone. Shale..... 1± Coal..... 16 Sandstone..... 17±	Speyer's coal mine. Opened 75 feet. Down dip of 22°.
38	SW. $\frac{1}{4}$ NW. $\frac{1}{4}$.	6	27 89	Shale..... Coal, good..... 6 4 Shale.....	Surface exposure.
39	SW. $\frac{1}{4}$ NW. $\frac{1}{4}$.	6	27 89	Shale..... 20 Coal, good..... 5 4 Shale..... 25 4	Surface exposure.
40	SE. $\frac{1}{4}$ NE. $\frac{1}{4}$.	1	27 90	Shale..... 1 4 Coal, good..... 2 5 Shale..... 1 4 9	Surface exposure.
41	NE. $\frac{1}{4}$ SW. $\frac{1}{4}$.	36	28 90	Covered. Coal..... 5+	Surface prospect.
42	SW. $\frac{1}{4}$ SE. $\frac{1}{4}$.	27	28 90	Coal..... 5	Abandoned coal mine. Vertical shaft 40 feet deep.

UNDIFFERENTIATED TERTIARY ROCKS.^a

The coal-bearing beds of the undifferentiated Tertiary are separated from the Laramie formation by an unconformity, above which is a noncoal-bearing series of soft shale and brown conglomeratic sandstones probably constituting the bottom part of the Tertiary. In the southern part of the field this formation is coal bearing in both the lower and upper portions.

The lower member is abundantly coal bearing near the railroad and becomes less so to the north. In T. 27 N., R. 90 W., this is the only part of the formation not covered by Wasatch beds, and it is apparently not coal bearing.

The upper member contains numerous coal beds of workable thickness between Riner and Fillmore, on the Union Pacific Railroad. To the northeast it disappears under Separation Flats and is concealed by Quaternary gravel and the overlapping Wasatch conglomerate. The highest dip is 7°, and within a short distance to the northwest the beds probably are horizontal. At Cherokee siding, in sec. 10, T. 20 N., R. 91 W., a prospect slope has been driven down a dip of 7° to a distance of 75 feet. At the old Fillmore station, in sec. 31, T. 21 N., R. 90 W., in an artesian well drilled by the Union Pacific Railroad Company, a 20-foot bed of coal was reported at a depth of 220 feet, a 10-foot bed at 270 feet, and a 15-foot bed at 320 feet. At Wamsutter, in sec. 34, T. 20 N., R. 94 W., in an artesian well put down by the same company, two 5-foot coal beds were found at depths of 150 and 220 feet. These beds probably belong to the upper member of the undifferentiated Tertiary.

The following sections show the general character and thickness of the coal beds of this formation. Nos. 43 to 49 occur in the lower member, and the remainder in the upper.

Sections of coal beds in the undifferentiated Tertiary deposits.

No. on Pl. XII.	Location.			Section of coal bed.	Remarks.
	Sec.	T.	R.		
43	NW. $\frac{1}{4}$ NW. $\frac{1}{4}$.	25	21	89	
44	SW. $\frac{1}{4}$ SW. $\frac{1}{4}$.	24	21	89	

^a Since this paper was written fossil plants have been collected from several horizons in these beds near Riner. The fossils have not been studied in detail, but are believed to be of Fort Union age.

Sections of coal beds in the undifferentiated Tertiary deposits—Continued.

No. on Pl. XII.	Location.			Section of coal bed.	Remarks.																			
	Sec.	T.	R.																					
45	SW. $\frac{1}{4}$ SW. $\frac{1}{4}$.	24	21	89	<table><tr><td>Shale.....</td><td><i>Ft. in.</i> 5</td></tr><tr><td>Coal, impure.....</td><td>11</td></tr><tr><td>Sandstone.....</td><td>6</td></tr><tr><td>Coal, good.....</td><td>3</td></tr><tr><td>Shale.....</td><td>1</td></tr><tr><td>Coal, good.....</td><td>3+</td></tr><tr><td></td><td>6 1+</td></tr></table>	Shale.....	<i>Ft. in.</i> 5	Coal, impure.....	11	Sandstone.....	6	Coal, good.....	3	Shale.....	1	Coal, good.....	3+		6 1+	Abandoned mine.				
Shale.....	<i>Ft. in.</i> 5																							
Coal, impure.....	11																							
Sandstone.....	6																							
Coal, good.....	3																							
Shale.....	1																							
Coal, good.....	3+																							
	6 1+																							
46	SW. $\frac{1}{4}$ SW. $\frac{1}{4}$.	12	21	89	<table><tr><td>Sandstone.....</td><td></td></tr><tr><td>Coal, impure.....</td><td>6</td></tr></table>	Sandstone.....		Coal, impure.....	6	Surface exposure.														
Sandstone.....																								
Coal, impure.....	6																							
47	SE. $\frac{1}{4}$ SW. $\frac{1}{4}$.	35	22	89	<table><tr><td>Shale.....</td><td>4</td></tr><tr><td>Coal, impure.....</td><td>2 6</td></tr><tr><td>Coal, good.....</td><td>6</td></tr><tr><td>Shale.....</td><td>2</td></tr><tr><td>Coal, impure.....</td><td>3</td></tr><tr><td>Shale.....</td><td>6</td></tr><tr><td>Coal, impure.....</td><td>1</td></tr><tr><td>Shale.....</td><td>3</td></tr><tr><td></td><td>19 3</td></tr></table>	Shale.....	4	Coal, impure.....	2 6	Coal, good.....	6	Shale.....	2	Coal, impure.....	3	Shale.....	6	Coal, impure.....	1	Shale.....	3		19 3	Surface exposure.
Shale.....	4																							
Coal, impure.....	2 6																							
Coal, good.....	6																							
Shale.....	2																							
Coal, impure.....	3																							
Shale.....	6																							
Coal, impure.....	1																							
Shale.....	3																							
	19 3																							
48	SE. $\frac{1}{4}$ NE. $\frac{1}{4}$.	18	24	89	<table><tr><td>Shale.....</td><td>1</td></tr><tr><td>Coal.....</td><td>2 6</td></tr><tr><td>Shale.....</td><td>1 4</td></tr><tr><td>Coal.....</td><td>1 2</td></tr><tr><td>Shale.....</td><td>6</td></tr></table>	Shale.....	1	Coal.....	2 6	Shale.....	1 4	Coal.....	1 2	Shale.....	6	Surface exposure.								
Shale.....	1																							
Coal.....	2 6																							
Shale.....	1 4																							
Coal.....	1 2																							
Shale.....	6																							
49	NE. $\frac{1}{4}$ SE. $\frac{1}{4}$.	20	26	90	<table><tr><td>Shale.....</td><td>11</td></tr><tr><td>Coal, good.....</td><td>4 1</td></tr><tr><td>Shale.....</td><td>2 6</td></tr><tr><td>Coal, good.....</td><td>4</td></tr><tr><td>Shale.....</td><td>1</td></tr><tr><td>Coal, impure.....</td><td>6</td></tr><tr><td>Shale.....</td><td>11</td></tr><tr><td>Coal, good.....</td><td>5</td></tr><tr><td>Shale.....</td><td>15 3</td></tr></table>	Shale.....	11	Coal, good.....	4 1	Shale.....	2 6	Coal, good.....	4	Shale.....	1	Coal, impure.....	6	Shale.....	11	Coal, good.....	5	Shale.....	15 3	Abandoned mine.
Shale.....	11																							
Coal, good.....	4 1																							
Shale.....	2 6																							
Coal, good.....	4																							
Shale.....	1																							
Coal, impure.....	6																							
Shale.....	11																							
Coal, good.....	5																							
Shale.....	15 3																							
50	SW. $\frac{1}{4}$ SW. $\frac{1}{4}$.	9	20	91	<table><tr><td>Shale.....</td><td></td></tr><tr><td>Coal.....</td><td>4</td></tr><tr><td>Shale.....</td><td></td></tr></table>	Shale.....		Coal.....	4	Shale.....		Surface exposure.												
Shale.....																								
Coal.....	4																							
Shale.....																								
51	NW. $\frac{1}{4}$ SE. $\frac{1}{4}$.	10	20	91	<table><tr><td>Shale, carbonaceous...</td><td>4</td></tr><tr><td>Coal.....</td><td>6 4+</td></tr><tr><td></td><td>10 4+</td></tr></table>	Shale, carbonaceous...	4	Coal.....	6 4+		10 4+	Entry 75 feet long. Down dip of 7°.												
Shale, carbonaceous...	4																							
Coal.....	6 4+																							
	10 4+																							
a 52	SE. $\frac{1}{4}$ SW. $\frac{1}{4}$.	12	20	91	<table><tr><td>Sandstone.....</td><td>3</td></tr><tr><td>Coal, impure.....</td><td>1 5</td></tr><tr><td>Shale.....</td><td>1</td></tr><tr><td>Coal, fair.....</td><td>4 2</td></tr><tr><td>Shale.....</td><td>4</td></tr><tr><td>Coal, fair.....</td><td>6</td></tr><tr><td>Bottom not exposed.</td><td>15 11</td></tr></table>	Sandstone.....	3	Coal, impure.....	1 5	Shale.....	1	Coal, fair.....	4 2	Shale.....	4	Coal, fair.....	6	Bottom not exposed.	15 11	Surface exposure.				
Sandstone.....	3																							
Coal, impure.....	1 5																							
Shale.....	1																							
Coal, fair.....	4 2																							
Shale.....	4																							
Coal, fair.....	6																							
Bottom not exposed.	15 11																							

^a This section is south of the Union Pacific Railroad and lies in the area mapped by M. W. Ball. (See pp. 243-255.)

WASATCH FORMATION.^a

The basal member of the Wasatch near the Union Pacific Railroad is very thin and contains numerous small granite pebbles. It thickens to the north and contains more and more conglomerate until in

^a These beds represent the lower part of the Wasatch group of Hayden (Rept. U. S. Geol. Survey Terr. for 1877, 1879, pp. 127-129). They also represent the lower part of the Vermilion Creek group of King (U. S. Geol. Expl. 40th Par., vol. 1, 1878, pp. 360-377), and have been traced into the type section on Vermilion Creek in northwestern Colorado.

the Green Mountains many of the granite boulders are 6 feet in diameter. The coal-bearing portion of the Wasatch immediately overlies this basal member and is present in the southern and western parts of the field only. Lithologically it resembles the upper member of the undifferentiated Tertiary, except that the shales have a slightly more pronounced color. The coal beds lie nearly horizontal, and their edges are in many places concealed by clinkers due to the burning of the coal.

Several prospect pits have been opened by the Union Pacific Railroad Company, and from them most of the following sections were taken:

Sections of coal beds of the Wasatch formation.

No. on Pl. XII.	Location.			Section of coal bed.	Remarks.
	Sec.	T.	R.		
53	SE. $\frac{1}{4}$ NW. $\frac{1}{4}$.	28	24	96	Prospect opened by sheep herders.
				Ft. in. Shale..... 6 Coal..... 2 6 Shale..... 5 Coal..... 1 9	
54	SW. $\frac{1}{4}$ SW. $\frac{1}{4}$.	19	24	95	Surface prospect.
				Shale..... 1 6+ Coal, bony..... 1 6 Shale..... 2 6 Coal..... 3 6 9+	
55	NW. $\frac{1}{4}$ NW. $\frac{1}{4}$.	2	22	95	Surface prospect.
				Shale..... Coal, good..... 5 3 Shale.....	
56	NE. $\frac{1}{4}$ SE. $\frac{1}{4}$.	21	23	94	Surface prospect.
				Sandstone..... 7 Shale..... 3 Coal, good..... 5 10 Shale..... 6 8	
57	NE. $\frac{1}{4}$ SE. $\frac{1}{4}$.	23	22	94	Surface prospect.
				Coal..... 10 Shale..... 1 Coal..... 4 Shale..... 1 Coal..... 2 Coal, impure..... 10 Coal..... 5 6+ 9 8+	
58	NE. $\frac{1}{4}$ NW. $\frac{1}{4}$.	29	22	94	Surface exposure.
				Shale..... Coal, bony..... 2 7 Coal, good..... 6 10 Clay..... 9 5	
59	NE. $\frac{1}{4}$ NE. $\frac{1}{4}$.	1	21	94	Surface exposure.
				Shale..... Coal, fair..... 3 4 Shale and sandstone... 5 4 Coal, fair..... 1 4 Shale, sandy..... 9 Coal, poor..... 3 19 3	
60	SW. $\frac{1}{4}$ SW. $\frac{1}{4}$.	3	21	94	Surface exposure.
				Sandstone..... 1 Coal..... 6 Shale..... 4 Coal, good..... 4 3 Shale..... 3 3 Coal, good..... 1 4 Bone..... 5 11 9	

Sections of coal beds of the Wasatch formation—Continued.

No. on Pl. XII.	Location.			Section of coal bed.	Remarks.
	Sec.	T.	R.		
61	NE. $\frac{1}{4}$ SW. $\frac{1}{4}$.	19	22	93	Surface prospect.
				<i>Ft. in.</i>	
				Shale.....	8
				Coal.....	5
				Shale, carbonaceous...	3 4
				Coal.....	1 5
				Bone.....	10
				Coal.....	3 7+
					10 3+
62	NW. $\frac{1}{4}$ SW. $\frac{1}{4}$.	3	20	93	Surface prospect.
				Shale.....	3
				Coal.....	2 11
				Coal, lignitic, brown	1 4
				Sandstone.....	2 1
					9 4
63	Center.	14	20	93	Surface prospect.
				Sandstone.....	2
				Coal.....	10 3
				Shale.....	7
				Coal, impure.....	2 1
				Shale.....	3 10
				Coal, impure.....	3 10
					18 9
64	SE. $\frac{1}{4}$ SE. $\frac{1}{4}$.	14	20	93	Surface prospect.
				Shale.....	7
				Coal.....	1
				Shale.....	1
				Coal.....	6
				Shale.....	7 8
65	SW. $\frac{1}{4}$ SW. $\frac{1}{4}$.	32	21	92	Surface exposure.
				Shale.....	
				Coal, very impure .	1
				Coal, fair.....	4 1
				Shale.....	5 1
66	SE. $\frac{1}{4}$ SE. $\frac{1}{4}$.	7	20	92	Surface prospect.
				Shale, carbonaceous...	4
				Coal.....	3 9
				Shale, carbonaceous...	1
					8 9

QUALITY OF THE COAL.

PHYSICAL PROPERTIES.

The quality of the coal of this area is very poorly shown by the analyses of samples collected within the field itself. Nowhere has development been carried beyond the zone of surface alteration. The coal of Mesaverde age is not exposed in this field except at the abandoned mine in sec. 22, T. 21 N., R. 88 W., and at a few small surface outcrops near Bull Springs. It is so badly weathered that its physical properties could not be studied. The remaining coals weather very rapidly. Several slopes have been driven to distances of about 75 feet in beds of the different zones, but the surfaces exposed in these slopes are badly weathered. Apparently fresh blocks of coal, obtained beneath the weathered surface, on exposure to the direct rays of the sun rapidly break up independently of the joint planes into smaller and smaller fragments with irregular faces, until the final fragments are about the size of a pea. The original blocks have a bright luster and many of them a slight conchoidal fracture. The resultant fragments are lusterless, and their surfaces do not show an

even fracture of any kind. Blocks of coal taken in 1905 from one of the mines in T. 27 N., R. 89 W., and kept in a shed with open windows were examined by the writer in October, 1907. They were large and firm, but the surface of the coal had lost its luster and was in places slightly checked. The specific gravity of the coal was considerably less than that of fresh coal from the same mine.

CHEMICAL PROPERTIES.

On account of the slight amount of development within this field, it was not possible to obtain good representative samples of the coal for chemical analysis. Only six samples^a were taken, and but one of these was obtained from a fresh working face. All these samples were collected near weathered surfaces and were probably more or less altered. A comparison of the coals of the same geologic age in the surrounding regions, where actual mining is being carried on and where good representative samples have been collected, shows the probable quality and character of the coals of this field. The analyses in the following table represent samples collected by A. C. Veatch in east-central Carbon County and by the writer in the field covered by this report:

Analyses of coal samples from the Great Divide Basin and adjacent coal fields, Wyoming.

[F. M. Stanton, chemist in charge.]

Geologic formation.....		Mesaverde.		Laramie.			
No. on Pl. XII.....				37.	35.	26.	
Laboratory No.....		b 3921.	b 3925.	5816.	5818.	5826.	b 3790. b 3548.
Sample as received:							
Prox.	Moisture.....	13.54	14.04	23.60	18.98	40.58	13.06 10.96
	Volatile matter.....	32.01	33.79	44.30	34.15	26.51	35.11 38.04
	Fixed carbon.....	48.34	45.58	28.00	40.22	30.21	48.86 48.59
	Ash.....	6.11	6.59	4.10	6.65	2.70	2.97 2.41
	Sulphur.....	.50	.40	.29	.51	.30	1.10 .29
Ult.	Hydrogen.....			5.95	5.87	6.50	5.52 5.37
	Carbon.....			53.60	53.58	37.38	61.72 62.25
	Nitrogen.....			.86	.87	.94	1.38 1.59
	Oxygen.....			35.20	32.52	52.18	27.31 28.09
	Calories.....			5,013	5,074	3,213	6,041 5,902
	British thermal units.....			9,023	9,133	5,783	10,874 10,624
Loss of moisture on air drying.....		7.00	5.20	8.30	7.10	26.80	3.70 .80
Air-dried sample:							
Prox.	Moisture.....	7.03	9.33	16.68	12.79	18.82	9.72 10.24
	Volatile matter.....	34.42	35.64	48.31	36.76	36.22	36.46 38.35
	Fixed carbon.....	51.98	48.08	30.54	43.29	41.27	50.74 48.98
	Ash.....	6.57	6.95	4.47	7.16	3.69	3.08 2.43
	Sulphur.....	.54	.42	.32	.55	.41	1.14 .29
Ult.	Hydrogen.....			5.49	5.47	4.78	5.31 5.32
	Carbon.....			58.45	57.67	51.07	64.09 62.75
	Nitrogen.....			.94	.94	1.28	1.43 1.61
	Oxygen.....			30.33	28.21	38.77	24.95 27.60
	Calories.....			5,467	5,462	4,389	6,273 5,950
	British thermal units.....			9,840	9,831	7,900	11,292 10,710
Thickness of coal bed sampled.....		<i>Ft. in.</i> 3 4	<i>Ft. in.</i> 4 2	<i>Ft. in.</i> 6 0	<i>Ft. in.</i> 4 6	<i>Ft. in.</i> 10 0	<i>Ft. in.</i> 5 6 7 3

^a These samples were collected according to the uniform method described by M. R. Campbell on pp. 12-13 of this volume. The analyses were made at the chemical laboratory of the fuel-testing plant of the United States Geological Survey at the Carnegie Technical Schools, Pittsburg, under the direction of F. M. Stanton, according to the methods described by N. W. Lord in Prof. Paper U. S. Geol. Survey No. 48, pt. 1, 1906, pp. 174-195, and in Bull. U. S. Geol. Survey No. 290, 1906, pp. 29-30.

^b Samples collected in the coal fields of east-central Carbon County. Veatch, A. C., Bull. U. S. Geol. Survey No. 316, 1907, pp. 253-258.

Analyses of coal samples from the Great Divide Basin and adjacent coal fields, Wyoming—
Continued.

Geologic formation.....		Undifferentiated Tertiary.							Wa- satch.
No. on Pl. XII.....		46.	51.						64.
Laboratory No.....		5815.	5817.	α 3808.	α 3826.	α 3806.	α 3610.	α 3605.	5949.
Sample as received:									
Prox.	Moisture.....	17.24	22.22	13.59	13.19	24.54	11.45	10.09	37.80
	Volatile matter.....	31.88	38.68	31.77	31.70	32.45	42.58	41.01	25.86
Ult.	Fixed carbon.....	49.28	30.25	49.35	50.23	37.38	39.33	41.91	22.30
	Ash.....	1.60	8.85	5.29	4.88	5.63	6.64	6.99	14.04
Ult.	Sulphur.....	.14	.66	.33	.24	.24	.38	.49	1.46
	Hydrogen.....	5.71	5.68	5.22			5.27	5.53	
Ult.	Carbon.....	59.08	50.19	61.05			59.66	62.66	
	Nitrogen.....	.33	.96	.83			.94	1.26	
Ult.	Oxygen.....	33.14	33.66	27.28			27.11	23.07	
	Calories.....	5,719	4,701	5,785			6,050	6,279	2,436
British thermal units.....		10,294	8,462	10,413			10,890	11,302	4,385
Loss of moisture on air drying.....		5.60	7.30	4.30	2.30	5.10	2.50	2.20	28.00
Air-dried sample:									
Prox.	Moisture.....	12.33	16.09	9.70	11.15	20.49	9.18	8.07	13.61
	Volatile matter.....	33.77	41.73	33.20	32.45	34.19	43.67	41.93	35.92
Ult.	Fixed carbon.....	52.20	32.63	51.57	51.41	39.39	40.34	42.85	30.97
	Ash.....	1.70	9.55	5.53	4.99	5.93	6.81	7.15	19.50
Ult.	Sulphur.....	.15	.71	.34	.25	.25	.39	.50	2.03
	Hydrogen.....	5.39	5.25	4.95			5.12	5.40	
Ult.	Carbon.....	62.58	54.14	63.80			61.19	64.07	
	Nitrogen.....	.35	1.04	.87			.96	1.29	
Ult.	Oxygen.....	29.83	29.31	24.51			25.53	21.59	
	Calories.....	6,058	5,071	6,045			6,205	6,420	3,383
British thermal units.....		10,905	9,128	10,881			11,169	11,556	6,090
Thickness of coal bed sampled.....			<i>Ft. in.</i> 5 4	<i>Ft. in.</i> 7 6	<i>Ft. in.</i> 7 0	<i>Ft. in.</i> 7 0	<i>Ft. in.</i> 8 0	<i>Ft. in.</i> 5 0	<i>Ft. in.</i> 7 6

^a Samples collected in the coal fields of east-central Carbon County. Veatch, A. C., Bull. U. S. Geol. Survey No. 316, 1907, pp. 253-258.

3921. Fort Steele, 20 miles north of, NE. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 9, T. 24 N., R. 85 W.

3925. Fort Steele, 25 miles northwest of, SE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 23, T. 25 N., R. 86 W.; upper part of bed, 7 feet 10 inches thick.

5816. Lost Soldier, 9 miles northeast of, SW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 6, T. 27 N., R. 89 W.

5818. Lost Soldier, 9 miles northeast of, SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 8, T. 27 N., R. 89 W. Abandoned slope.

5826. Lost Soldier, $\frac{1}{2}$ miles east of, NE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 16, T. 26 N., R. 90 W. Abandoned tunnel.

3790. Hanna, 16 miles northwest of, SW. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 11, T. 24 N., R. 83 W.

3548. Walcott, 9 miles southeast of, NW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 1, T. 20 N., R. 83 W.

5815. Rawlins, 8 miles west of, SW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 12, T. 21 N., R. 89 W. Surface exposure.

5817. Cherokee siding, 100 yards north of, NW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 10, T. 20 N., R. 91 W. Abandoned slope.

3808. Walcott, 12 miles north of, NW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 25, T. 23 N., R. 84 W.

3826. Walcott, 12 miles north of, SE. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 25, T. 23 N., R. 84 W.

3806. Same; surface sample.

3610. Hanna; lower bench of No. 2 bed.

3605. Hanna; lower part of top bench of No. 1 bed.

5949. Latham; one-half mile northwest of, SE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 14, T. 20 N., R. 93 W. Shallow prospect.

COMPARATIVE VALUE OF COALS.

MESAVERDE COAL.

The coals of Mesaverde age are not developed to any great extent in this field. In the region just south of Rawlins and along the western edge of the Hanna field the openings and prospects are shallow and are worked for local use only. One of these, the Dillon mine (abandoned), 4 miles southwest of Rawlins, is filled with water below a depth of about 350 feet. Samples from the Mesaverde formation at Rock Springs^a show heating values ranging from 11,101 to 12,271 British thermal units on samples as received, and from 11,574 to 12,782 British thermal units on air-dried samples. Samples taken from prospects and openings similar to those south of

^a See report by A. R. Schultz, pp. 256-282 of this volume.

Rawlins, on the same coals, show heating values ranging from 8,339 to 10,849 British thermal units on samples as received, and from 8,806 to 11,567 British thermal units on air-dried samples. From these two sets of figures it is evident that samples taken from surface openings and prospects do not represent the true value of the coals. It is probable that more extensive development of the Mesaverde coals near Rawlins will prove them to be bituminous coals comparing favorably with the best of those at Rock Springs.

LARAMIE COAL.

The Laramie coals of this field are somewhat inferior to the Mesaverde coals. The percentage of ash is somewhat smaller, but the moisture content is greater, and in three of the samples much greater, than in the Mesaverde coals. No. 5816 was taken about 15 feet down the dip from a prospect which had been filled with mud and water for nearly ten years. No. 6826 was taken from an abandoned drift only a few feet above the dry course of Lost Soldier Creek. The drift has probably been subjected to flooding in the spring for several years past. Nos. 3790 and 3548 were taken by A. C. Veatch^a from better openings in central Carbon County, and probably represent more nearly the true value of the coal.

UNDIFFERENTIATED TERTIARY COAL.

The coals of the undifferentiated Tertiary have been developed very little in this field. The only entry or drift of any considerable size was driven several years ago in a nearly horizontal bed in the upper part of the formation near Cherokee Siding. This coal occurs in about the same part of the formation as that mined at Hanna, in central Carbon County. Analyses Nos. 3610 and 3605, representing samples from Hanna, according to Veatch,^a show a fairly good low-grade bituminous coal. It is not improbable that the coal of the same age in this field, if developed beyond the zone of surface alteration, would be of similar quality. Sample No. 5815 was taken from lens-shaped masses of brittle, shiny coal found in one of the beds of the lower part of the formation, and probably represents local peculiarities in the coal.

WASATCH COAL.

No prospects of any great depth have been opened from which representative samples of the Wasatch coals could be obtained. Sample No. 5949 was taken from a shallow surface prospect and was very badly weathered. The effect of weathering on the coals of this formation may be readily seen by comparing samples Nos. 5930 and 5374 with Nos. 5375 and 5367.^b In the first two samples, which

^a Bull. U. S. Geol. Survey No. 316, 1907, pp. 253-258.

^b See report by A. R. Schultz, pp. 256-282 of this volume.

were taken from a mine and a prospect, the percentages of moisture and ash are much less than in the other two, which were taken from surface croppings, and the calorific values in British thermal units are correspondingly higher. If, as it seems reasonable to believe, the effect of weathering on these coals is similar throughout this rather small basin, the Wasatch coals of the area covered by this report should show a heating value of more than 10,500 British thermal units, and they should be considered as high-grade subbituminous coals.

HISTORY OF DEVELOPMENT.

Coal was first developed in this region by the Union Pacific Railroad Company in 1868, in secs. 24 and 25, T. 21 N., R. 89 W. Hayden^a makes the following statement concerning the operations there:

Near Separation, about 10 miles west of Rawlings Springs [Rawlins], a coal mine has been opened with a bed of coal 11 feet in thickness. I am inclined to believe that it is really the same bed as the one opened at Carbon, and also near Rock Creek and Coopers Creek. The strata dip nearly west about 10°. The mine has been opened from the summit of the hill, and the bed followed down the inclination, so that all the coal will have to be taken up the grade, and the difficulties in drainage will be greatly increased. The coal is of most excellent quality. There is, above and below the coal, the usual drab indurated clay. Below the clay is a bed of gray ferruginous sandstone.

This mine was abandoned in a short time on account of difficulty of mining and distance from the railroad.^b

No further development was attempted in this field until recent years. Along the eastern and northeastern border several small mines have been opened to supply coal for local use. In sec. 22, T. 21 N., R. 88 W., a mine (p. 227) was opened on a bed of coal of Mesa-verde age. The bed has a thickness of 8 feet 4 inches and is nearly vertical. A slope was driven down in the bed with an inclination of 30° until water was encountered at a distance of 80 feet. At this point work was abandoned on account of the difficulty of mining economically a bed so nearly vertical.

Shallow mines have been opened on beds of Laramie age in sec. 18, T. 25 N., R. 89 W., and secs. 4 and 16, T. 26 N., R. 90 W., from which coal was taken for local use, but these have been abandoned. In sec. 8, T. 27 N., R. 89 W., two mines were developed on separate beds of the same age to a depth of about 100 feet along the slope, but were abandoned when ground-water level was reached. A new mine is now being opened in sec. 6, T. 27 N., R. 89 W., by Frederick C. Speyer, of Split Rock, Wyo., in a 16-foot bed, the lower of the two just referred to, which dips 26° SW. The slope is being driven down the dip and has reached a distance of 75 feet. The lower 10 feet of the coal is being removed and the remainder left for a roof. The coal

^a Hayden, F. V., Repts. U. S. Geol. Survey Terr. for 1867, 1868, and 1869, 1873, pp. 97, 98.

^b Lesquereux, Leo, Rept. U. S. Geol. Survey Terr. for 1872, 1873, p. 333.

is being consumed on the ranches of the Sweetwater Valley. In sec. 27, T. 28 N., R. 90 W., a shaft 4 feet square has been sunk for about 40 feet down a vertical coal bed of Laramie age 5 feet thick, but it is now abandoned and is caving in. In sec. 20, T. 26 N., R. 90 W., coal has been mined from a bed in the undifferentiated Tertiary for use at the Lost Soldier stage station, but the mine is now abandoned and caved.

FUTURE DEVELOPMENT.

Several conditions will influence the future development of the coal of the area. They are (1) accessibility, (2) water supply, (3) timber supply, and (4) market.

ACCESSIBILITY.

The coal of this region is readily accessible. The Union Pacific Railroad borders the field on the south, and branch lines from it could easily be constructed to any part of the field. By the construction of a railroad from Knobs northward along Separation Flats all the coal on the east side of the field as far as the gap between Whisky Peak and the Ferris Mountains could be easily reached. In case a railroad should be built along the line surveyed by the Nebraska, Wyoming and Western in Tps. 24 and 25 N., the coals of the east-central portion of the region would be easily accessible. A preliminary survey has also been made up the valley of the Sweetwater. If this line is constructed in the near future, as it seems reasonable to believe, the coals of the Muddy Creek region will be the nearest to the railroad in central Wyoming and will be in great demand.

WATER SUPPLY.

The scarcity of water throughout the field has considerable bearing on the economic development of the coal. Water may probably be obtained in any part of the field by drilling to relatively shallow depths, but the water so obtained may be highly alkaline and unsuitable both for steam and domestic purposes, unless some means is adopted for the precipitation of the salts. Artesian wells have been drilled at several stations between Rawlins and Tipton by the Union Pacific Railroad Company. In nearly all of them water was obtained within 600 feet of the surface, but it was too alkaline for use in the locomotives. At Riner water is pumped from a 1,600-foot artesian well and also from a 1,400-foot well drilled at Old Fillmore and connected with Riner by a pipe line. Water from these wells is used to supplement the supply brought in the tenders and water cars from Wamsutter and Rawlins. At Wamsutter water is obtained from a depth of 1,300 feet in a 1,600-foot well. The water from all three of these wells is strongly alka-

line, but it is the best that has been found between North Platte River and Point of Rocks. It is used merely because the haulage of water for locomotive use on this portion of the road is too expensive.

In any part of the field water as good as that obtained at Wamsutter could probably be found by boring to about the same depth. Until late in the summer of 1907 all the water for about 3,000 men and for the development of the coal mines at Superior was brought by rail from Green River. Recently artesian water, which will probably furnish a supply sufficient to meet the demand, has been obtained at Superior. Any extensive mining development will have to be supplied with water in a similar way from sources outside of the field until deep wells can be put down.

TIMBER SUPPLY.

The roofs of most of the coal beds are very poor and mines will have to be extensively timbered. The area is devoid of timber except along the crests of the Ferris and Green mountains, where timber is abundant enough to supply extensive operations in the northeastern part of the field. Timber for the remainder of the area will probably have to be brought by rail from other localities in the surrounding Rocky Mountain region, and will be a large item in the expense of mining the coal.

MARKET.

This field is situated in about the center of the coal fields of southern Wyoming. Its coal should have the same market as that at present shipped from the Rock Springs and Hanna fields. Coal from these two fields has been carried eastward as far as Omaha, where it comes into competition with the coals of Iowa and Missouri; southward as far as Denver, where it is marketed with the Colorado coals; northward to the Black Hills, where it competes with the Sheridan and Cambria coals; and westward as far as the Pacific coast. During 1907 the demand of western markets became so great that eastward shipments from Rock Springs were entirely abandoned and all the commercial coal produced was sent westward. The construction of the proposed railroad up the Sweetwater will extend this market eastward down the valley of North Platte River and northward to the Owl Creek Mountains.

The local market for the coal will be very slight. Outside of Rawlins its use will be confined to a few scattering ranches and to the development of the mineral resources of the surrounding mountains.

THE WESTERN PART OF THE LITTLE SNAKE RIVER COAL FIELD, WYOMING.

By MAX W. BALL.

INTRODUCTION.

This paper is a brief statement of the results of a survey made in 1907 by the writer, assisted by B. L. Johnson, J. T. Singewald, jr., L. Reinecke, Robert D. Sawin, and for a month early in the season by V. H. Barnett. Geologic and topographic mapping was done on a scale of 2 inches to the mile. Locations were determined by pacing from land-subdivision corners; elevations were based on aneroid-barometer readings, controlled by a line of levels run diagonally across the field from Rawlins to Baggs.

The map (Pl. XIII) accompanying this paper has been compiled from the field sheets to show only the more prominent cultural and drainage features and the main geologic facts related to the occurrence of coal. The boundaries of the coal-bearing formations are indicated, but no attempt is made on this map to show the location of actual coal outcrops. With the exception of a few corner stones near Five Buttes and a few stones that were established along Muddy Creek by E. Lambert, county surveyor, no land corners were ever set in Tps. 14, 15, and 16 N., in this field, and the location on the map of the features in this part of the field can not be considered accurate. In preparing the present base map the lengths of the land lines as given on the plats of the original Land Office surveys were accepted as correct and were plotted by so balancing the recorded distances about vertical and horizontal right lines intersecting near the center of the map that the distortions due to convergence of meridians and errors of surveying were distributed equally over the sheet. As a result of this balanced plotting of distances rather than directions the length of the sides of any given township or section is the same as that shown on the Land Office plat, but the shape of the township or section may be different from the shape given on that plat or from the shape which would be obtained if the balance lines were located in some other position. Thus this map does not exactly agree with the map of

the Great Divide Basin field (Pl. XII), or with the map of the east-central Carbon County fields,^a both of which were plotted about balance lines intersecting near their own centers. When the entire Wyoming area of the Little Snake River field shall have been surveyed, a final report will be published, accompanied by a complete contour map.

The writer wishes to acknowledge the receipt of valuable information and assistance from the Union Pacific Railroad Company; E. Lambert, county surveyor, Carbon County; W. S. Smith, M. W. Dillon, L. Calvert, A. Stratton, and others.

GEOGRAPHY.

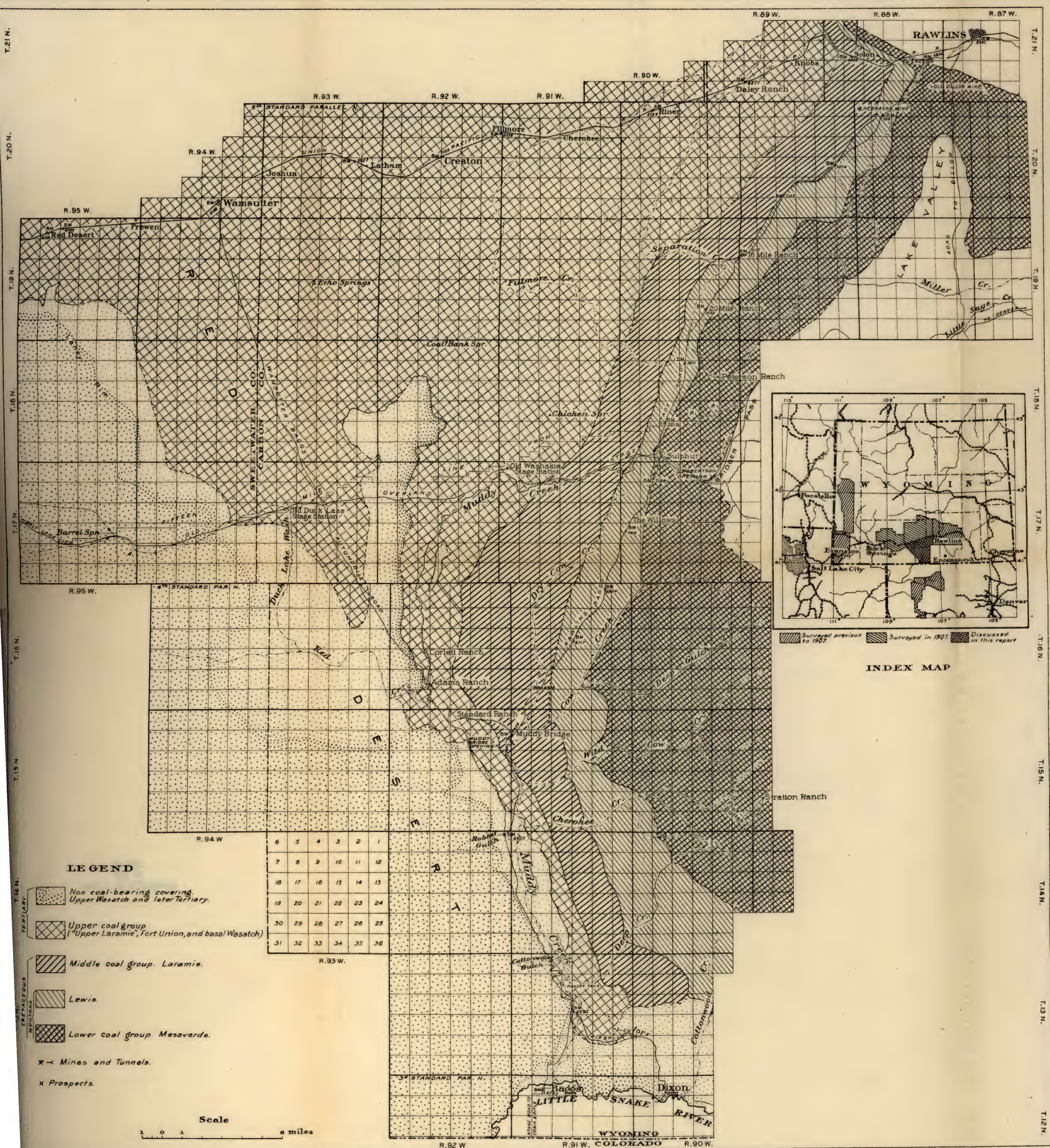
The coal field drained by Little Snake River extends from the Sierra Madre westward to and partly into the Red Desert, and from the summit of the Elkhead Mountains of Colorado northward to the divide between the Pacific and Great Divide Basin drainages, a few miles south of the Union Pacific Railroad.

The area discussed in this paper is located near the middle of the southern boundary of the State. It extends along the Union Pacific Railroad from Rawlins to Red Desert station, and southward to Little Snake River between Baggs and Dixon. It comprises all except the southeast corner of the Wyoming portion of the Little Snake River field, as well as that part of the Great Divide Basin field which lies south of the Union Pacific Railroad and east of range 96. It joins along the Union Pacific Railroad with the work of E. E. Smith in the Great Divide Basin field (pp. 220-242), at the northwest corner with that of A. R. Schultz in the Rock Springs field (pp. 256-282), and at the northeast corner with the mapping of A. C. Veatch^a in 1906 in the Kindt coal basin. It is separated by the Elkhead Mountains from the Yampa field mapped by Fenneman and Gale in 1905.^b

The eastern part of the area consists of high plateaus and ridges cut by deep, rocky canyons. West of this is a depression, in places a simple valley, elsewhere a broad area of low, irregular relief. It is followed by a series of hogbacks and low transverse ridges which in the north end of the field give place gradually to the broad, comparatively level expanse of gentle dip slopes, dry lake beds, and alkali flats forming the eastern border of the Red Desert. The level expanse is terminated on the west by the brilliant red and white escarpment of the Laney Rim, and on the south by the highly colored bluffs which extend eastward from Flat Top Mountain and which south of the mouth of Red Creek form the western boundary of the

^a Veatch, A. C., Map of the coal fields of east-central Carbon County, Wyo.: Bull. U. S. Geol. Survey No. 316, 1907, Pl. XIV.

^b Fenneman, N. M., and Gale, H. S., The Yampa coal field, Routt County, Colo.: Bull. U. S. Geol. Survey No. 297, 1906.



MAP OF THE WESTERN PART OF THE LITTLE SNAKE RIVER COAL FIELD, WYOMING

By Max W. Ball and Bertram L. Johnson

hogback region. Westward from the Laney Rim and the bluffs which constitute its southerly extension lies a great area of badlands, broken dip slopes, and isolated buttes.

A prominent terrace extends southward from Creston to a point north of Coal Bank Spring, whence it runs southeastward, terminating just west of the Rawlins-Baggs stage road about midway between Sulphur and the headwaters of Fillmore Creek. Formerly the crest of this terrace was considered and described as a part of the Continental Divide, but the investigations of 1906 and 1907 show that although for a short distance it constitutes the divide between Little Snake River and the Great Divide Basin, the greater part of the terrace lies within the Great Divide Basin.

The relatively low relief of the greater part of the area makes the coals readily accessible. Wagon roads of easy grade reach all present openings and pass near almost all prominent outcrops. Railroad connection to some of the coals lying high up on the Mesaverde plateaus would involve some moderately difficult engineering, but most of the Mesaverde and all of the higher coals could be reached by easy and inexpensive railroad construction.

Lack of timber and scarcity of water present serious difficulties in the development of the coals. The area is devoid of timber except for a few small cedars on the ridges east of Sixteenmile and Twenty-mile ranches. There is, however, an abundance of timber in the Elkhead Mountains to the south, and in the southern part of the Sierra Madre, southeast of the area.

The surface water supply of the region is scanty, consisting, besides half a dozen alkaline springs, of a few streams which head in the plateaus and high ridges forming the eastern part of the area, and continue permanent for short distances after leaving the higher country. The amount of water obtainable by wells is best indicated by the borings made by the Union Pacific Railroad Company along the north edge of the field. These results indicate that a supply of water could be obtained in most parts of the field within a few hundred feet of the surface. This water, however, west of the center of the valley which lies just west of the plateau region, will be highly alkaline. Deeper wells, 1,500 feet or more, would probably give an abundance of water which, though very hard, would be much better than that obtained nearer the surface.

GEOLOGY.

STRATIGRAPHY.

GENERAL SECTION.

The stratigraphic relations of the coal-bearing and associated formations, with their general character and approximate thicknesses, are shown in the following table:

Generalized section of coal-bearing rocks in western portion of the Little Snake River coal field, Wyoming.

System.	Formation.		Economic designation.	Description.	Thickness in feet.	
					North end of field.	South end of field.
Tertiary.	Upper part of Wasatch and later Tertiary.			Variegated clay, passing upward into brown and gray shales, sands, and sandstones. Not coal bearing.	Top	not seen.
	Wasatch.			Shale and soft sandstone, with many beds of impure coal. Conglomerate.		
	(?) ^a	Upper coal group.		Gray and brown sandstones and gray and drab shales, with many coal beds. White to dark clay shale. No coal. Heavy sandstone, with interbedded shale and numerous beds of good coal; conglomerate at the base.	8,500	0 to 4,000
Cretaceous.	Laramie formation. ^b	Middle coal group.		Brown and gray shaly and concretionary sandstones and dark shale, with several beds of coal. In the southern end of the field the lower half is yellow, softer, and more sandy and apparently contains little coal. Marine fossils in base.	4,000	0 to 2,500
	Lewis shale.			Drab, slightly sandy, highly gypsiferous shale, with a few thin, soft sandstones. Not coal bearing.	1,600	2,300(?)
	Mesaverde formation.	Lower coal group.		Upper and lower members consist of heavy sandstone with a few interbedded shales. Intermediate member consists of shaly sandstone and shale. Upper member coal bearing.	2,500	Bottom not seen.
				Dark drab, concretionary, calcareous shale, with several thin, soft, brown sandstones. Not coal bearing.	Bottom	not seen.

^aThe three lower members of the upper coal group have the stratigraphic position of the "Upper Laramie" of A. C. Veatch, Coal fields of east-central Carbon County, Wyo.: Bull. U. S. Geol. Survey No. 316, 1907, pp. 244-260.

^b This formation is the equivalent of the "Lower Laramie" of the report noted above.

SHALE.

The shale which underlies the lower coal group is equivalent to the upper part of the Mancos shale, as that formation has been described and mapped in western Colorado. The shale is dark drab in color, somewhat concretionary, and very calcareous, and contains numerous thin, soft brown sandstones, especially near the top. The shale is not coal bearing.

MESAVERDE FORMATION.

The full thickness of the Mesaverde or lower coal group was studied only in the north end of the field. Where observed the basal third of the formation consists of light-colored, massive sandstone, much

of it strongly cross-bedded, with a few interbedded gray and drab shales. No coal bed of workable thickness was found in this part of the formation. Overlying the basal member is a series of sandstone, shaly sandstone, and shale beds, in many places producing a region of minor relief between the prominent ridges or escarpments formed by the upper and lower members. The upper third of the formation closely resembles the basal member, but the sandstones are somewhat thinner and less prominently cross-bedded. This upper member contains a few thin beds of good coal in the north end of the field, the number and thickness of the beds increasing toward the south. The Dillon mine, southwest of Rawlins, and the Robertson opening, just east of Sulphur, are on beds at the base of this member.

LEWIS SHALE.

The Lewis shale is dark drab, slightly sandy, somewhat concretionary, and highly gypsiferous. It contains a few thin, soft sandstones which increase in number toward the north end of the field. It weathers rapidly, producing a depression between the ridges of Mesaverde sandstone on the one side and those of the Laramie on the other. It was not found to be coal bearing.

LARAMIE FORMATION.

In the north end of the field the Laramie or middle coal group is made up of interstratified gray and brown sandstones, shaly sandstone, concretionary sandstone, and brown and black shales, with a number of beds of coal. The base of the formation as mapped is a massive white sandstone, usually forming an escarpment. Marine Montana (Lewis) fossils were in places found as high as 400 feet above this sandstone. Farther south the lower half of the formation is softer and more sandy until in the south end of the field it consists of yellow, poorly consolidated, thin-bedded sandstone, with a few beds of resistant sandstone and drab shale. Coal beds seem to be less abundant in this part of the formation toward the south, although their apparent scarcity may be due to the fact that the poorly consolidated sandstone weathers rapidly and does not produce good outcrops. The upper half of the formation continues unchanged throughout the area. The coals of the Laramie formation have been very little prospected, the Nebraska mine southwest of Rawlins being the only opening.

UPPER COAL GROUP.

The basal member of the upper coal group is composed of gray and brown sandstones, with interbedded gray, brown, and drab shales and numerous beds of coal. The sandstones are thicker, more numerous, and more massive toward the base, which is marked by a bed that is extremely massive, cross-bedded, in many places highly ferruginous,

and as a rule somewhat conglomeratic. The pebbles of the conglomerate are small and usually chert, although near the Union Pacific Railroad fragments of Carboniferous limestone and Cretaceous shale were observed by E. E. Smith.^a Smith found that in the area north of the railroad this conglomeratic sandstone is underlain by a mass of beds about 800 feet thick composed of alternating layers of shale and rusty-brown conglomeratic sandstone, the latter decreasing in number, thickness, and conglomeratic character toward the bottom. For several miles south of the railroad there are no satisfactory exposures to show the southward extent of these beds. In the southern portion of the area the heavy sandstone is separated by 3 to 100 feet of dark shale from a thin bed of rather coarse, highly quartzose conglomerate with chert pebbles held in a matrix of coarse chert and crystalline quartz. In some places a second conglomerate is separated by about 100 feet of shale from the first. The coal beds of this member are the most extensively prospected in the area, the Muddy Bridge and Dixon Cut-off openings and a number of smaller prospects being on these beds.

Overlying the basal member is a member consisting of clay shale and sandy clay, with a small, extremely variable amount of soft sandstone, either massive or thin bedded. In the most northerly exposures, which occur about midway between Coal Bank and Chicken springs, the clay is white and the sandstone gray, whereas farther south the color of the rocks is gray, brown, and, near the river, almost black. In some places toward the south the beds contain large quantities of cherty conglomerate; in other places this conglomerate is confined to the top or to the top and bottom, and elsewhere it is absent. This member contains no coal beds.

Gray and brown sandstones with interbedded gray, brown, and drab shales and numerous coal beds compose the next member. The coal beds have not been prospected, although very prominently exposed at Coal Bank Spring and along the ridge west of Fillmore Creek.

The division between the uppermost or fourth member and the one underlying it is based on a conglomerate which Smith^a observed in the north end of the Great Divide Basin and traced southward to Fillmore, finding evidence of unconformity. The conglomerate was observed for about 4 miles south of the Union Pacific Railroad, showing distinct unconformity; but beyond that point it is completely obscured by gravel and other covering. Lithologically the beds above the conglomerate resemble those immediately below, consisting of interstratified gray and brown sandstones and brown, drab, and black shales, with many beds of impure coal, and near the top a peculiar brown shale weathering greenish.

^a See table, pp. 224-225.

Regarding the age of the upper coal group, the paleontologic evidence, principally botanical, from the three lower members, conflicts, pointing partly to the "Upper Laramie," as it is known in east-central Carbon County, and partly to the Fort Union, with most of the evidence favoring the latter; but the position and lithologic character of the beds very strongly suggest the former. Paleontologic evidence determines the uppermost member to be almost certainly basal Wasatch.

UPPER WASATCH AND LATER TERTIARY BEDS.

Unconformably overlying the upper coal group is a succession of brilliant red and white, somewhat sandy clays, with a few gray and brown shales and soft sandstones, the latter in places finely conglomeratic. Higher in the beds the red coloring is less prominent, appearing here and there in isolated patches which decrease in number and size until the beds are entirely composed of white, gray, brown, and drab shales, clay, and unconsolidated sand, with a few gray and brown sandstones. Although brilliant red is the ordinary and prominent color, the roughly bedded clays at the base are in places purple, green, drab, and yellow. Along Little Snake River the clays are gray and white, with the usual number of gray and brown sandstones, which here, as elsewhere in the field, are in places finely conglomeratic. Near the river the basal member seems to be a whitish or yellowish sandstone, highly calcareous in places and generally conglomeratic, and is difficult to distinguish in isolated exposures from the sandstones of any of the three coal groups.

Near the Union Pacific Railroad these beds overlie the uppermost member of the upper coal group. To the south they successively overlap the underlying beds to the middle of the clay-shale member of the upper coal group, and along Little Snake River they swing abruptly eastward, covering everything down to the Mesaverde formation.

The basal portion of this group of beds is upper Wasatch, probably corresponding in position to the Knight formation^a of Uinta County; the overlying rocks belong in the Green River and Bridger formations.

STRUCTURE.

Between Rawlins and Lake Valley a shallow syncline separates the Rawlins dome from the north end of the Sierra Madre uplift, and connects the Mesaverde coal beds of the Little Snake River field with those of the Kindt Basin.^b Outside of this small part near Rawlins the structure of the area is extremely simple, the formations dipping regularly to the west, forming the eastern limb of the great

^a Veatch, A. C., Geography and geology of a portion of southwestern Wyoming: Prof. Paper U. S. Geol. Survey No. 56, 1907, pp. 92-96.

^b Veatch, A. C., Coal fields of east-central Carbon County, Wyo.: Bull. U. S. Geol. Survey No. 316, 1907, p. 250.

Green River Basin. In the north end of the field the beds change gradually from a dip of 25° on the eastern margin of the coal field to a practically horizontal position along the Union Pacific Railroad west of Latham, forming here the south end of the shallow syncline which is the main structural feature of the Great Divide Basin. All the westward-dipping formations south of a line drawn roughly from Red Desert station through Echo, Coal Bank, and Chicken springs lie on the eastern slope of what King ^a called the Washakie Basin, the northeast corner of which is indicated by the angle of the Laney Rim. The beds composing this rim strike parallel to the railroad with a very low southerly dip as far east as a point south of Red Desert, where they turn southeastward, dipping from 2° to 4° SW. Throughout the south end of the area the Mesaverde and Laramie formations dip 12° or less to the west. Near the top of the Laramie the dip increases to 28° , and this dip prevails to the place where the lower beds disappear beneath the overlapping upper Wasatch, which here, as farther north, dips 1° to 4° W.

The simplicity of structure and general low dips of the field favor easy and economic development of the coals. So far as observed no faults of any appreciable magnitude disturb the continuity of the coal beds anywhere in the field. That minor faults are present in the region of folded rocks near Rawlins is shown by the following statement by M. W. Dillon regarding the Dillon mine: "The first fault is a downthrow of 4 feet about 200 feet from the portal, the next is an upthrow of 4 feet 240 feet from the portal, and the next a downthrow of 6 feet about 450 feet from the portal of the slope."

THE COAL.

PHYSICAL PROPERTIES.

The Mesaverde coal as exposed at the Dillon mine is very compact and hard. As there are no surface exposures of this bed in the vicinity, it was impossible to determine the effects of surface weathering, but in the mine the coal is black and clean, with a submetallic luster, showing a smooth, unweathered face down to the water which at present fills the bottom of the slope. At the Robertson opening the Mesaverde coal presents a clean, compact face without partings or inferior streaks.

The Laramie coal bed exposed at the Nebraska mine is composed of alternations of clean, firm coal and softer, slightly crumbly layers which weather rapidly. The coal in the harder benches is black and compact, and has a slightly resinous luster.

The beds of the basal member of the upper coal group are made up of benches of coal with thin partings of bone. The coals are not so compact, clean, or black as those of the Mesaverde, and they weather

^a U. S. Geol. Explor. 40th Par., Atlas, 1876, Map 11.

much more rapidly, having a cracked or minutely jointed appearance in surface exposures, with selenite and ferrous sulphate in the cracks and along the joint planes.

The coals in the next higher coal-bearing member of the upper coal group occur in zones as much as 60 feet thick, composed of coal beds from 1 to 10 feet thick, separated by beds of sandstone and shale of about the same thickness. Although some of the coal is clean and firm, much of it is dirty and shaly, and all seems to air slack rapidly. Selenite and ferrous sulphate are present in the coal in large quantities.

Only a few exposures of the coals of the topmost member of the upper coal group were encountered. The occurrence of the beds is similar to that in the next lower member, but the coal is for the most part dirty, shaly, and gypsiferous. Small seams of brown coal appear among the beds, showing the nearness of the coals to true lignites.

SECTIONS AND ANALYSES.

Wherever it was possible to procure samples of coal not too much weathered, they were taken and forwarded to the fuel-testing laboratory at Pittsburg, Pa., where they were analyzed under the direction of F. M. Stanton. Sampling was done according to the regulations given on page 12. Detailed sections of all good exposures encountered were measured. The tables below give the analyses of all samples obtained, sections of all beds sampled, showing the thickness of the bed represented by the sample, and a sufficient number of additional sections to represent each coal-bearing zone by one or more typical sections.

Analyses of coal samples from western part of Little Snake River coal field, Wyoming.

[F. M. Stanton, chemist in charge.]

Name of formation.....		Mesaverde, near base of upper member		Lara- mie.	Upper coal group, basal member.				
Laboratory No.....		5297.	5340.	5324.	5298.	5342.	5448.	5447.	5299.
Sample as received:									
Prox.	Moisture.....	10.14	13.62	19.20	20.68	25.04	23.99	26.02	10.26
	Volatile matter.....	33.87	34.55	36.46	35.97	46.74	28.49	30.08	22.23
	Fixed carbon.....	47.55	43.14	40.56	33.45	20.71	39.41	37.85	57.68
	Ash.....	8.44	8.69	3.78	9.90	7.51	8.11	6.05	9.83
	Sulphur.....	.49	1.44	.34	1.11	.39	.97	1.01	.87
	Hydrogen.....	5.17	5.53	5.74	5.44	5.55			2.72
	Carbon.....	63.75	58.78	58.88	51.84	51.13			67.94
	Nitrogen.....	1.32	.89	1.34	.72	.73			.77
	Oxygen.....	20.83	24.66	29.92	30.99	34.69			17.87
	Calories.....	6,116	5,744	5,401	4,843	4,680	4,499	4,641	5,752
British thermal units.....		11,009	10,339	9,722	8,717	8,424	8,098	8,354	10,354
Loss of moisture on air drying.....		2.40	1.90	2.30	5.80	6.50	9.80	12.80	1.70
Air-dried sample:									
Prox.	Moisture.....	7.93	11.95	17.30	15.80	19.83	15.73	15.16	8.71
	Volatile matter.....	34.70	35.22	37.32	38.18	49.99	31.59	34.49	22.61
	Fixed carbon.....	48.72	43.97	41.51	35.51	22.15	43.69	43.41	58.68
	Ash.....	8.65	8.86	3.87	10.51	8.03	8.99	6.94	10.00
	Sulphur.....	.50	1.47	.35	1.18	.42	1.08	1.16	.89
	Hydrogen.....	5.02	5.42	5.61	5.10	5.17			2.57
	Carbon.....	65.32	59.93	60.27	55.03	54.68			69.12
	Nitrogen.....	1.35	.91	1.37	.76	.78			.78
	Oxygen.....	19.16	23.41	28.53	27.42	30.92			16.64
	Calories.....	6,266	5,855	5,528	5,141	5,005	4,988	5,322	5,851
British thermal units.....		11,280	10,539	9,951	9,254	9,010	8,978	9,580	10,533
Thickness of coal.....		<i>Ft. in.</i> 4 6	<i>Ft. in.</i> 11 0	<i>Ft. in.</i> 8 0	<i>Ft. in.</i> 2 1	<i>Ft. in.</i> 2 5	<i>Ft. in.</i> 6 0	<i>Ft. in.</i> 12 0	<i>Ft. in.</i> 2 2

In addition to the results shown in the table, a determination of volatile matter by a modified method was reported. This differs from the method adopted by the American Chemical Society for obtaining the volatile matter in that the sample is given four minutes of preliminary heating over a low flame, then seven minutes over the full flame of a Bunsen burner, while in the regular method there is no heating preliminary to the seven minutes over the full Bunsen flame.^a Sample No. 5342 in the table gives a rather startling proximate analysis by the regular method, as shown by comparing it with No. 5298, taken from another bench of the same bed. By the modified method the volatile matter in the two samples is as follows:

No. 5298, as received.....	27.90
No. 5298, air dried.....	29.62
No. 5342, as received.....	27.04
No. 5342, air dried.....	28.92

F. M. Stanton, chemist in charge, writes concerning sample No. 5342:

The high volatile matter does not indicate very much in this kind of coal, and I would suggest that in any classification on this coal the modified volatile results be used. We have found repeatedly that volatile matter in high-moisture coals is very unsatisfactory as determined by the official method, while the modified method gives very concordant and satisfactory results on all types of coal and lignite.

Location, geologic position, and sections of coal beds in western part of Little Snake River field, Wyoming.

Formation.	Economic designation.	Member.	Laboratory No.	Location.	Section of bed.
					<i>Fl. in.</i>
		Upper member.		Latham, $6\frac{1}{2}$ miles south of; SW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 23, T. 19 N., R. 93 W.	Shale, gray..... 6 Coal, dirty..... 6 Shale, gray..... 7 Coal, shaly, gypsiferous..... 7 Shale, gray..... 6 Coal, shaly..... 4 Shale, bituminous..... 2 Coal, shaly..... 2 Shale, brown..... 26
	Upper coal group.	Third member from base.		Creston, 9 miles south of; Coal Bank Spring; NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 3, T. 18 N., R. 92 W.	6 1 3 2 5 4 2 1 3 9 8 6 10 4 3 3 9 8 2 6 10 2 61

^a For complete description of the modified method and general comparison of results by the two methods, see Bull. U. S. Geol. Survey No. 323, 1907, pp. 36-39.

Location, geologic position, and sections of coal beds sampled in western part of Little Snake River field, Wyoming—Continued.

Formation.	Economic designation.	Member.	Laboratory No.	Location.	Section of bed.
Laramie.	Upper coal group.	Basal member.	5298, 5342	Muddy Bridge stage station, 1 mile west of; NW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 12, T. 15 N., R. 92 W.	Shale, bituminous..... Shale, brown..... Coal..... Shale, gray..... Coal..... Shale..... Coal, slightly dirty..... <i>Ft. in.</i> 6 5 2 1 2 5 2 2 4 8 8
			5448	Baggs, 5 miles northeast of; NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 23, T. 13 N., R. 91 W.	Bone..... Coal, slightly dirty..... Bottom not exposed. 6 4
			5447	Baggs, 4 $\frac{1}{2}$ miles northeast of; SW. $\frac{1}{4}$ sec. 24, T. 13 N., R. 91 W.	Coal, dirty..... Bone..... Coal, dirty..... Bone..... Coal, good..... Shale, bituminous..... 3 2 3 10 2 12 16 5
			5299	Baggs, 24 miles north of; SE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 4, T. 16 N., R. 92 W.	Coal, burned..... Shale..... Coal..... Bottom not exposed. 15 3 2 2 20 2
			5324	Rawlins, 6 miles southwest of; NE. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 6, T. 20 N., R. 88 W.	Coal, firm..... Coal, slightly crumbly..... Coal..... Coal, crumbly..... 4 1 6 2 6 8
	Mesaverde.	Near base of upper member.		Muddy Bridge stage station, 1 mile southeast of; SE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 7, T. 15 N., R. 91 W.	Coal..... Shale..... Coal..... 1 10 4 5 10
			5297	Rawlins, 3 miles southwest of; NE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 36, T. 21 N., R. 88 W.	Coal..... Coal, slightly dirty..... Coal..... 2 10 2 1 6 4 6
			5340	Sulphur stage station, 1 $\frac{1}{2}$ miles east of; SE. $\frac{1}{4}$ sec. 4, T. 17 N., R. 90 W.	Coal..... Bottom not exposed. 11

BURNING.

Much of the coal of this field is burned along the outcrop. The amount of burning is relatively small in the Mesaverde and about equally prominent in each of the other coal-bearing formations. In some places the effects on the adjacent rocks can be seen several feet from the actual seat of burning; in others, rocks a very short distance away are not affected. A quarter of a mile southeast of Muddy Bridge a small caved drift in the Laramie formation exposes about 18 inches of highly bituminous shale underlain by a few feet of dirty coal. Near by the bituminous shale has been burned out, causing

sintering and slumping of the overlying shaly sandstone, but the dirty coal composing the lower part of the bed is apparently not affected. In this connection attention should be called to the fact that sample No. 5299 in the table above was taken from a 2-foot bed separated by 3 feet of shale from 15 feet of burned coal. The physical appearance of the bed sampled was not altered by the burning, but the chemical analysis shows decided differences between this sample and the others collected from the same zone; notably, increased fuel value; lower air-drying loss; low volatile matter and high fixed carbon, giving high fuel ratio; and, in the ultimate analysis, low hydrogen and oxygen and high carbon. Thus this coal in close proximity to a burned bed has by alteration become of considerably higher grade than its unaffected neighbors.

RELATIVE VALUE.

Unfortunately there are in this field no openings on the coals of the two upper members of the upper coal group, and it was impossible to procure unweathered samples of these beds for analysis. The samples, all from the three lower coal-bearing zones, have lower fuel values than the samples from the same zones collected by Veatch^a in the east-central Carbon County fields in 1906. This may be due to the greater amount of folding in the rocks of the eastern fields, but it must be borne in mind that most of the samples collected in eastern Carbon County were from working mines or other adequate openings, whereas of the samples from this field two are from abandoned mines and the remainder from prospects. The eastern Carbon County samples, then, represent coal which is much fresher, less weathered, and nearer the true value than the samples from this field.

With the exception of the coal No. 5299, which is believed to have increased in value by the burning of an adjacent bed, the coals of this field decrease in value from the lowest to the highest coal-bearing zones; from bituminous coal at the Dillon mine through increasingly low-grade subbituminous almost to lignite in the uppermost member of the upper coal group.

DEVELOPMENT.

Development in the area has been confined to a slight amount of prospecting and a few small openings to supply the local demand. The Dillon mine (Mesaverde) produced good coal for several years prior to 1900 or 1901. M. W. Dillon, the original owner of the mine, says the mine was closed down by the people to whom he sold it because faults were encountered in the rooms. The coal was used in Rawlins, 3 miles away, as was also that of the Nebraska mine (Laramie), 4 miles southwest of the Dillon opening.

^a Bull. U. S. Geol. Survey No. 316, 1907, pp. 253-258.

The remaining development consists of a small opening in the Mesaverde about a mile east of Sulphur and another opening in the base of the upper coal group a mile west of Muddy Bridge, the product of each being used by two or three ranches in its neighborhood; a few prospect drifts and slopes in Coal and Cut-off gulches, between 4 and 5 miles northeast of Baggs; and some small prospects in the hogbacks east of Muddy Creek, between the Corlett ranch and the old Washakie stage station.

Although the present demand for coal is greater than the supply, further development in this field does not seem probable until the good coals have railroad connections. The markets to the east and west along the Union Pacific Railroad are supplied by the Hanna, Rock Springs, and Uinta County coals, and a possible southern outlet over the Denver, Northwestern and Pacific Railway, now building, is blocked by the Yampa field of Routt County, Colo.

The Union Pacific Railroad Company is contemplating a line from either Rawlins or Wamsutter southward across the field through Baggs to Craig, Colo. If it is built from Rawlins the Mesaverde coals in the eastern part of the area will be developed; if from Wamsutter, the basal upper-group coals from the old Washakie stage station southward will probably be opened; and in either case the coals near Little Snake River will be thoroughly prospected and worked. The natural market, however, for the Little Snake River coals is in the Encampment copper district, which lies along the Sierra Madre on the eastern border of the field.

THE NORTHERN PART OF THE ROCK SPRINGS COAL FIELD, SWEETWATER COUNTY, WYOMING.

By A. R. SCHULTZ.

INTRODUCTION.

This paper is a brief preliminary statement of the results of a geologic survey of the northern part of the Rock Springs coal field, Wyoming, made during the summer of 1907.^a The region mapped, with the exception of two townships, was covered by the public-land surveys. A considerable tract was resurveyed by the General Land Office in 1906 and twenty-four townships were resurveyed in 1907. As economic considerations demanded that the work be based primarily on the Land Office subdivisions, because these subdivisions are the units of economic importance, it was necessary to do different kinds of work in different parts of the field.

In the areas where resurvey inspection work was carried on, the geologic work was executed in connection with the inspection. All geologic locations along the land lines, as well as within the township sections, were measured by stadia. An idea of the accuracy of the location of coal prospects, outcrops of coal beds, and fossil localities may be had from the fact that approximately ninety locations were obtained in each square mile.

In the unsurveyed townships, T. 23 N., Rs. 103 and 104 W., it was necessary to establish Government corners before the lands could be classified. In this area detailed geologic mapping was carried on in connection with the subdivision work, and a complete geologic map, showing all the coal croppings and prospect pits, was made as that work progressed. The geologic and topographic locations, as well as the line measurements, were made by stadia.

Outside of the areas of detailed mapping all locations were made by pacing section lines or from land corners found by such pacing. Lines were run one-fourth to one-half mile apart, and all the more important coal beds were traversed and the traverses tied to land corners.

^a The personnel of the parties engaged in mapping the geology changed from time to time, as they were transferred to other fields or left in order to take up other work. The men assisting in the geologic mapping were V. H. Barnett, G. E. Burton, J. L. Rieh, G. C. Matson, J. J. Galloway, E. B. Hopkins, W. B. Heroy, and J. T. Singewald. Of these, only the first two were with the party for the entire season.

The field sheets, on a scale of 2 inches to the mile, contour interval 50 feet, are now being compiled into a base map on a scale of 1 inch to the mile. This map will be used in the preparation of the geologic and other maps of the final report. The sketch map (Pl. XIV) accompanying this report has been prepared from the field sheets to show the more prominent cultural, drainage, and economic features, and although approximately correct, it may be found to differ in minor particulars from the final large-scale map.

TOPOGRAPHIC FEATURES.

The field here considered lies along the eastern margin of the great Green River Basin and includes in part, on the east, the Great Divide Basin. It lies on the north flank of the Rock Springs dome, which is completely surrounded by Tertiary beds and does not form a topographic basin. Within this field there are six distinct topographic districts, each presenting an entirely different character and texture from those of its neighbor. Only the most prominent peaks and ridges that encircle the dome rise above the adjacent Tertiary escarpments. The divide between the Green River and Great Divide basins has no topographic identity or distinctness. It lies for the most part several miles east of the Rock Springs dome and is formed in some places by Tertiary rock, in others by Cretaceous rock, and in still others by igneous rock. The divide is irregular, extending across several distinct topographic districts.

Within the field the principal topographic features are due to (1) hard, resistant sandstone of the Mesaverde; (2) hard, resistant limestone and sandstones of the nearly horizontal Green River and Wasatch formations; (3) migrating sands; (4) soft beds of the Wasatch, and (5) igneous rock.

The hard, resistant sandstone of the Mesaverde makes notably concentric ranges of hills more or less continuous about the central portion of the Rock Springs dome. These concentric ridges contain the most important coal beds of the field and are usually separated from each other and from areas of equal or more elevated younger rocks by belts of low relief. The two most pronounced depressions are carved in the soft shale overlying and underlying the Mesaverde sandstone. These low valleys are natural routes of travel and afford easy access from the railroad to the more rugged ridges containing the coal. The shale below the Mesaverde gives rise to low relief along the central part of Rock Springs dome.

The hard, resistant limestones and sandstones of the Green River and Wasatch formations produce notable table-like forms, bounded by prominent escarpments of considerable length. In places the harder layers in these beds produce bench after bench in regular succession, separated by nearly parallel valleys. The more prominent

ridges form in many places precipitous bluffs, while in parts of the field the beds present characteristic badland topography.

Huge sand dunes formed by the migrating sands are the most conspicuous topographic feature in the northern part of the field.

The soft beds of the Wasatch form a low depression along the synclinal trough of the Great Divide Basin. This formation contains numerous beds of coal, few of which are well exposed. The topographic features are such that the coals are readily accessible.

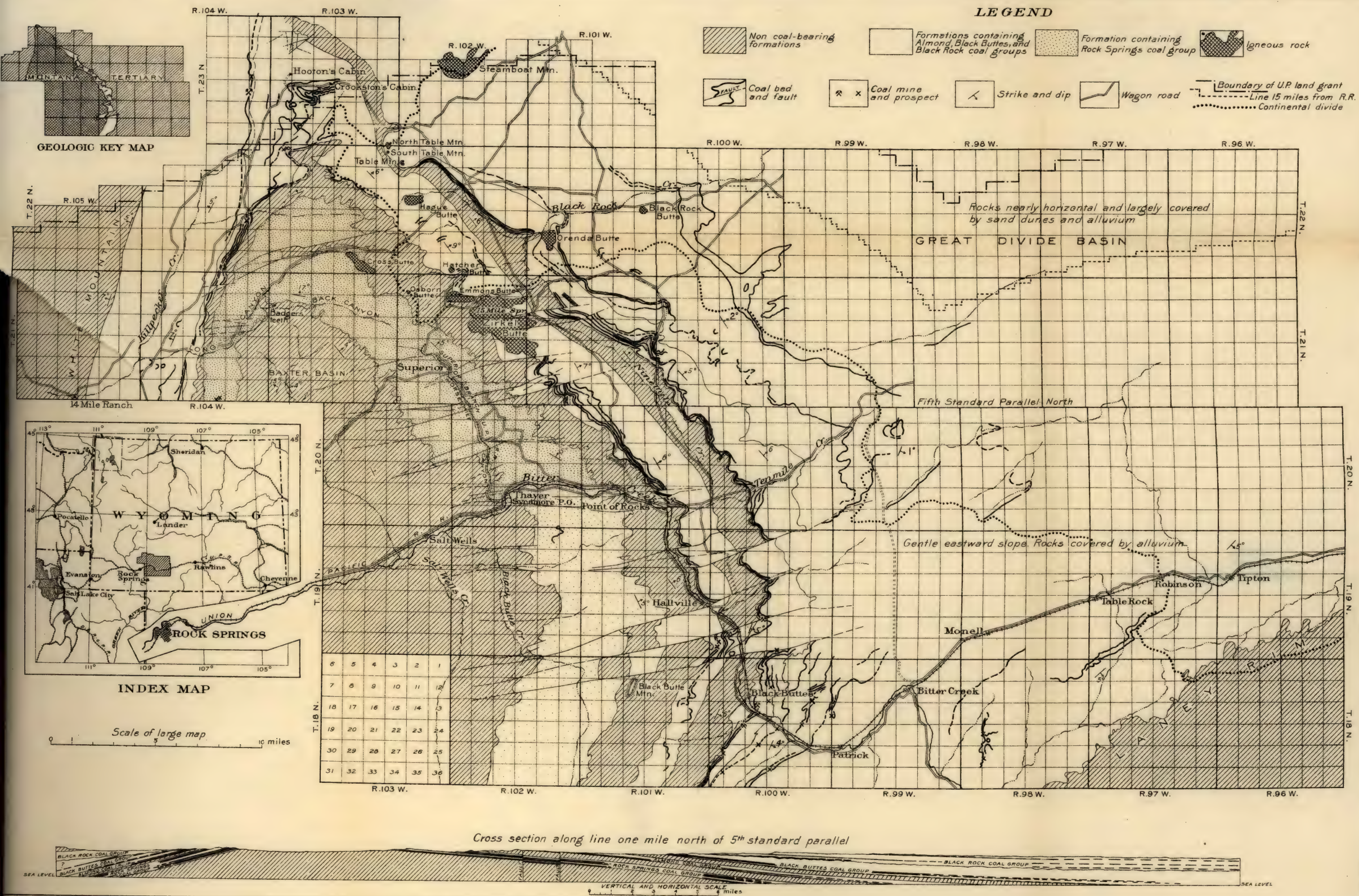
In this field igneous rocks rise like landmarks out of the arid plateaus of the Red Desert. The lava forming these rocks flowed from a little group of volcanoes far removed from similar centers of igneous activity. Their nearly concentric cones, needle-like necks, irregular dikes, and table-like sheets afford a striking contrast to the topographic features of the surrounding hills.

The drainage for the most part flows to the Pacific coast. Part of the area, however, on the northeast lies within the Great Divide Basin, which has no outlet. The main drainage is not affected by the Rock Springs dome, which in a way connects the two mountain ranges, Uinta and Wind River. Bitter Creek, the only prominent stream in this field, flows across the central portion of the dome at nearly right angles to the major axis and has carved a broad valley, along which the Union Pacific Railroad was constructed. The three large tributaries of Bitter Creek, however, have been shaped indirectly by the fold. On account of the difference in the hardness of the beds these valleys extend along the strike of the beds and are approximately at right angles to Bitter Creek. All the area not tributary to Bitter Creek drains to the east, and the water flows into the Great Divide Basin, which includes an area of approximately 4,200 square miles. The divide between these two drainage systems lies along the crest of Cathedral Bluff or Laney Rim, swings northwestward and crosses the Union Pacific Railroad track just west of Robinson, thence trends in a northwesterly direction to Steamboat Mountain, thence northward to South Pass, where the east and west divides reunite.

The location of this divide within the area may be seen on the accompanying map, Pl. XIV, also on Pl. XII.

In the Great Divide Basin there are numerous small dry lake beds, alkali lakes, and alkali, clay, and red flats, the largest being the Red Desert flat, near the center of the basin. In the northern part of the field, within the sand-dune area, there are also numerous small lakes that are fed by melting snow and ice in and beneath the sand dunes. Throughout this region very few rocks are exposed, and the dip slopes are well covered by gravel and loose soil.

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MAP OF THE NORTHERN PART OF THE ROCK SPRINGS COAL FIELD, SWEETWATER COUNTY, WYOMING.
By A. R. Schultz and B. W. Lewis.

GEOLOGY.

STRATIGRAPHY.

OUTLINE OF GEOLOGIC SUCCESSION.

The present investigation led to the conclusion that the subdivisions previously mapped by King and Powell could not be applied to the sequence of rock in this region. The fossils collected by this party and studied by F. H. Knowlton and T. W. Stanton indicate that the several formations have the geologic time values indicated in the accompanying table, where the general character and succession of the Cretaceous and Tertiary rocks, together with their economic importance, are set forth.

Section of Cretaceous and Tertiary rocks of Sweetwater County, Wyo.

System.	Group.	Formation.	Economic designation.	Thickness in feet.	Description.	Economic value.
Tertiary.		Green River.		350	Massive irregular bedded sandstone.	
		Unconformity.				
		Green River.		600	Thin-bedded shales, sandstones, and limestones, some of which are oolitic, for the most part light colored, white, gray, yellow, or greenish.	Most important spring horizon. Contains some coal.
		Unconformity.				
				400 to 825	Variegated clays, shales, and sandstones, the sandstones in places being slightly conglomeratic.	
Cretaceous.		Wasatch. ^a	Black Rock coal group.	1,200 to 2,650	Alternating layers of white, yellow, and brown sandstones, gray, drab, and carbonaceous shales, with coal beds and conglomerate containing granite and quartzite pebbles. Numerous bands of white concretionary sandstone weathering in irregular shapes. Basal sandstone is conglomeratic.	Prolifically coal bearing. Many thin beds of coal, and at least one bed 25 feet thick occurs in this group. No mines working this coal. One prospect east of Hallville. Coal mined for ranch use at Hooton's prospect, T. 23 N., R. 104 E. Yields artesian water. Flowing well at Bitter Creek.
		Unconformity.				
		Laramie (?)	Black Buttes coal group.	±2,371	Massive basal bed of white and yellow sandstones, showing traces of conglomerate in places; forms prominent scarp. The overlying bed consists of variable sandstones, clay, and coal beds. Fossils abound in places.	Coal bearing. Numerous important beds. Old mine opened and worked on these beds near Black Buttes station. New mine opened in 1907 south of Black Buttes. Prospects at various points. May yield artesian water.

^a Abundant collections of plants have been obtained from the lower third of this formation and determined by F. H. Knowlton, who studied the collection, as undoubtedly Fort Union.

Section of Cretaceous and Tertiary rocks of Sweetwater County, Wyo.—Continued.

System.	Group.	Formation.	Economic designation.	Thickness in feet.	Description.	Economic value.
Cretaceous.	Montana.	Lewis shale.		± 750	Dark gray, drab, and black shales, highly gypsiferous, with some soft shaly sandstones and large concretions. Produces region of low relief.	Possible source of clay beds. Natural routes of travel. Not known to be coal bearing.
			Almond coal group.	900	Soft white and brown sandstones, sandy shale, and clay, with numerous beds of coal and bituminous shale.	Coal bearing. Many coal beds. Numerous prospects throughout the field. Coal from these beds has been mined at Rock Springs and Point of Rocks.
				800	Massive white and yellowish sandstones, with little shale and ferruginous matter. Upper third conglomeratic, with fine black and gray quartz pebbles. Sandstone forms pronounced escarpments and hogback ridges.	Yields artesian water in parts of field.
		Mesaverde	Rock Springs coal group.	2,400	White to yellow sandstone, interbedded shale and clay with several large coal beds and numerous thin beds ranging from a few inches to 2 or 3 feet. The heaviest sandstones are grouped near the base of the formation.	Prolifically coal bearing. Many large coal beds and numerous smaller beds. Best coal in the Rock Springs field. Important mines at Rock Springs and Superior. Many prospects and drifts opened. Artesian-water zone. Flowing wells at Superior and Rock Springs.
				860	Drab, yellow, and brown sandstones and interbedded shale and shaly sandstone with little or no bituminous matter. Massive sandstones are grouped near top of formation, giving rise to the "Golden Wall."	Important artesian-water zone.
				940	Shaly sandstone and arenaceous shale, in places highly gypsiferous. Much of it very friable, producing low benches and badland ridges.	
				+ 550	Black and drab shales, very soft and friable.	

COAL-BEARING FORMATIONS.

MESAVERDE.

The oldest coal-bearing rocks exposed in this area are of Montana age. It is possible that the Frontier formation of the Colorado group may contain workable beds of coal, and that along the axis of the

dome in the vicinity of Baxter Station these may lie near enough to the surface to be mined some day, but at present no borings have penetrated deep enough to reveal them, and information is lacking regarding their depth and existence. In this field the Mesaverde consists of four distinct members, two of which are coal bearing. The lowest member, as well as the beds underlying, consists chiefly of sandstone, shaly sandstone, and shale, all of which are barren of coal and show no indications of bituminous matter. The two coal-bearing members of the Mesaverde are separated from each other by a massive white sandstone, approximately 800 feet thick. The lower group of coal beds is known as the Rock Springs coal group, and the other as the Almond coal group. The Almond coal group is overlain by noncoal-bearing shale which corresponds to the Lewis shale in other parts of the Rocky Mountain region.

Rock Springs coal group.—The Rock Springs coal group is the most important and the one containing the highest grade of coal in this area. Its basal portion consists of heavy, ridge-making, coal-bearing sandstones and the remainder of brown, yellow, and white sandstones, shale, clay, and interbedded coal. The group is prolifically coal bearing throughout and contains at least twelve coal beds ranging from 2 to 10 feet in thickness and many other beds less than 2 feet thick. These beds occur somewhat regularly throughout the group and are fairly persistent along the strike. They have been prospected all the way from Rock Springs to Superior. Very little prospecting has been done south of Superior. In this locality the coal beds are somewhat thinner, and the number of the beds is not so great as it is between Superior and Rock Springs. The coal is, however, of high grade, and additional mines are certain to be opened in the near future. Mines are in operation on beds of this group at Rock Springs and Superior, upper beds being worked at both places, and at Gunn the coal beds near the base of the group are being opened. New mines were to be opened last season north of Rock Springs along Killpecker Valley and at Gunn camp, northwest of Baxter, but owing to the money stringency work was greatly delayed and some of it temporarily abandoned. In Rock Springs all the mines now in operation, with the exception of mine No. 1 of the Union Pacific Coal Company, are working the No. 7 bed. No. 1 mine is working the No. 1 bed, which is stratigraphically higher than No. 7. The area underlain by the Rock Springs coal was mapped in detail, and the locations of mines, prospect pits, and coal crops were determined by means of stadia. The locations of the outcrops of the more important coal beds and of the mines and prospect pits and tunnels are shown on Pl. XV.





DETAILED MAP OF THE NORTHERN PART OF THE ROCK SPRINGS COAL ZONE, WYOMING
By A. R. Schultz and B. W. Lewis

ated for a short time, and then abandoned, as the coal is inferior to the Rock Springs coal.

The following sections, which are a few of the numerous measurements made of these beds, will show their character and thickness:

Sections of coal beds in the Almond coal group.

Location.			Section of coal bed.	Ft. in.	Location.			Section of coal bed.	Ft. in.
Sec.	T.	R.			Sec.	T.	R.		
NW. $\frac{1}{4}$ NE. $\frac{1}{4}$.	32	21	101	Sandstone and shale. Coal..... 4 Shale..... 1 2 Sandstone.. 2+	NE. $\frac{1}{4}$ NE. $\frac{1}{4}$.	6	22	103	Sandstone... 1+ Coal..... 5 Sandstone... 1+
				7 2+					7+
SE. $\frac{1}{4}$ NE. $\frac{1}{4}$.	3	21	104	Shale..... 1 2 Coal..... 3 Sandstone.. 2	NW. $\frac{1}{4}$ NW. $\frac{1}{4}$.	24	22	104	Shale..... 2+ Coal..... 6 Sandstone... 1+
				6 2					9+
NE. $\frac{1}{4}$ SE. $\frac{1}{4}$.	3	21	104	Sandstone.. 3 Coal..... 7 Sandstone and shale.	NW. $\frac{1}{4}$ SE. $\frac{1}{4}$.	26	22	104	Sandstone... 1+ Coal..... 2 6 Sandstone... 1+
				10					4 6+
NE. $\frac{1}{4}$ SE. $\frac{1}{4}$.	16	21	104	Shale and sandstone Coal..... 7 Sandstone.. 2+	NE. $\frac{1}{4}$ NE. $\frac{1}{4}$.	35	22	104	Shale and sandstone. 6 Coal..... 6 Sandstone... 2
				9+					14

POST-MONTANA.

Overlying the Lewis shale occur two groups of coal beds, separated from each other by an unconformity of considerable magnitude. For convenience in the following discussion the lower will be called the Black Buttes coal group and the upper the Black Rock coal group. The unconformity between these two groups may in places readily escape observation.

Black Buttes coal group.—Along the east side of the dome the Black Buttes coal group lies conformably upon marine Lewis shale, which weathers readily and produces regions of low relief. The basal member of the Black Buttes coal group consists of a massive bed of yellowish-white sandstone, in places over 100 feet thick and not known to be coal bearing. This member, resting upon the soft, friable Lewis shale, forms steep hills and cliffs along the contact. The rocks above this sandstone consist of a series of variable sandstone, clay, and coal beds that lie exposed in the low hills and ridges east of the main scarp. On the west side of the dome this group is absent and the Black Rock group rests unconformably upon the Almond coal group, and all traces of the Black Buttes group and Lewis shale are concealed by overlap. Considerable prospecting has been done at various places along this coal zone, and good beds of coal exposed.

deep. Around the margin there is every evidence of very recent slumping. Along one of the cracks a current of hot air is continually rising. The odor of coal gas is very strong, and the temperature of the air at the mouth of the crack is about 120°. It was impossible to determine from the exposure how deep the burning coal bed is located, but it is certain that it is more than 10 feet below the surface. A short distance north of this sink is another large one in which a heavy white sandstone bed has dropped down 15 to 20 feet. Cracks in the sandstone along the edge show a depth of about 25 feet without revealing burning coal. Coal for local ranch use is being mined at Hooten's prospect, in sec 24, T. 23 N., R. 104 W.

The following representative sections illustrate the thickness and character of the coal beds of the Black Rock group:

Sections of coal beds in the Black Rock coal group.

Location.			Section of coal bed.	Location.			Section of coal bed.
Sec.	T.	R.		Sec.	T.	R.	
SW. $\frac{1}{4}$ NW. $\frac{1}{4}$.	20	18	98	NE. $\frac{1}{4}$ SE. $\frac{1}{4}$.	7	21	100
NE. $\frac{1}{4}$ SW. $\frac{1}{4}$.	29	18	98	NW. $\frac{1}{4}$ SW. $\frac{1}{4}$.	34	21	100
NE. $\frac{1}{4}$ SW. $\frac{1}{4}$.	18	18	99	NE. $\frac{1}{4}$ NE. $\frac{1}{4}$.	11	21	101
SW. $\frac{1}{4}$ NW. $\frac{1}{4}$.	18	18	99	SE. $\frac{1}{4}$ NE. $\frac{1}{4}$.	7	21	104
NW. $\frac{1}{4}$ NW. $\frac{1}{4}$.	34	18	100	NW. $\frac{1}{4}$ NW. $\frac{1}{4}$.	17	22	100
NE. $\frac{1}{4}$ NE. $\frac{1}{4}$.	28	19	100	NE. $\frac{1}{4}$ SW. $\frac{1}{4}$.	24	22	104
NE. $\frac{1}{4}$ NW. $\frac{1}{4}$.	28	21	99	SE. $\frac{1}{4}$ SW. $\frac{1}{4}$.	21	18	100
				NW. $\frac{1}{4}$ NE. $\frac{1}{4}$.	23	18	100

Sections of coal beds in the Black Rock coal group—Continued.

Location.				Section of coal bed.	Location.				Section of coal bed.
Sec.		T.	R.		Sec.		T.	R.	
NE. $\frac{1}{4}$ NE. $\frac{1}{4}$.	31	18	100		SE. $\frac{1}{4}$ SE. $\frac{1}{4}$.	13	23	104	
SE. $\frac{1}{4}$ SE. $\frac{1}{4}$.	11	18	100		SE. $\frac{1}{4}$ NE. $\frac{1}{4}$.	24	23	104	

The third or Black Buttes coal group rests conformably upon the underlying formations and occupies a belt extending along the east side of the dome, but not concentric with the overlying formations. Along the west side of the dome the beds comprising the Black Buttes coal group are covered by the Black Rock group, which rests directly upon the beds that make up the second or Almond zone, but along the east side of the dome the Black Buttes zone is separated from the Almond zone by a belt of non-coal-bearing Lewis shale.

The fourth or Black Rock coal group lies unconformably upon the older (Black Buttes) beds, and unlike them occupies a concentric belt around the dome. The Black Rock coal zone spreads over a large area in the northeastern part of the field and occupies a large portion of the Great Divide Basin. The same group contains the coals in the low synclinal trough between the Rock Springs dome and the Rawlins anticline. For the eastern boundary of this coal zone the reader is referred to the reports on the Great Divide Basin coal field (pp. 220-242) and the Little Snake River coal field (pp. 243-255) in this volume.

FAULTS.

The simple dome structure above referred to is somewhat complicated by many normal faults of considerable throw. Here and there the horizontal displacement amounts to nearly 3 miles, but the vertical displacement is usually less than 100 feet and in few localities reaches several hundred feet. Northeast of Salt Wells, in T. 20 N., R. 103 W., nine large faults cut the rocks along the east township line within a distance of less than 5 miles. Not uncommonly three separate and distinct faults occur within less than 1 mile.

Some of the faults extend across the entire arch of the dome, others extend only across one limb or part of one limb, and still others extend for a few hundred feet or a mile or two and then die out. Some of the larger faults have been traced for a distance of more than 20 miles. The trend of the faults is nearly at right angles to the strike of the rocks, or across the limbs of the anticline. This is particularly true near the north end of the dome, where the faults cut some of the rocks at right angles to their strike and, before dying out, continue approximately along the strike of the underlying beds. The position of the larger faults is shown on Pls. XIV and XV.

In addition to the larger faults, readily detected on the surface, numerous small faults are encountered in mine workings. In the Rock Springs coal group, from the Van Dyke bed upward, there is at many places a system of characteristic joints or slips that part the coal at short intervals from roof to floor. These slips incline toward the south and present every peculiarity of a fault. Along

many of them there is an actual displacement of one-half inch to a foot or more. Much slickensided coal is present along such surfaces. As a rule these small faults do not interfere with mining, but rather assist in breaking or parting the coal, thus making it easier to mine. The larger faults, however, greatly increase the difficulties in mining and tend to retard development work. In regions of much faulting the offsetting of the coal beds may so increase the cost of mining that the mines will be abandoned or development work stopped.

IGNEOUS ROCKS.

At the north end of the dome numerous intrusive and extrusive masses have been forced up through the Cretaceous and Tertiary rocks and cap these rocks in several localities. The exposures of leucite range from talus-covered hills, isolated volcanic necks, and associated dikes to lava flows with cones, intruded sheets, and dikes. Many of the lava sheets present abrupt walls from 50 to 150 feet in height. Some of the lava flows and volcanic necks lie along fault lines, through which the molten mass may have found an outlet; elsewhere the lava seems to have eaten its way through the rocks without causing any disturbance, as the sedimentary beds lie practically horizontal all around the igneous masses, which contain many fragmentary inclusions of sedimentary rock. No bulging or distortion was noted in the vicinity of the leucite. Although the lavas cut many coal beds and rocks of the coal-bearing formations, in no place were the coal and igneous rock seen in actual contact. Coal samples were collected from two prospect pits in sec. 10, T. 21 N., R. 102 W., a few rods below the overlying lava sheet and about a mile from several volcanic cones, but no apparent difference was observed in the physical and chemical properties of the coal.

QUALITY OF COAL.

PHYSICAL PROPERTIES.

The Rock Springs coal is jet-black as it comes from the mine, has a bright or even glassy luster, and in places shows beautiful iridescent colors. The structure of the bedding planes is as a rule well preserved, but jointing is not strongly developed. The coal is dense in texture and somewhat brittle. The streak ranges in color from brownish black to black. Many slickensided surfaces are present in this coal, as well as numerous small faults displacing the bedding planes from a fraction of an inch to several inches. Considerable deposits of salts occur on the faces of the coal and on the sandstones along the entries in the mines. The coal on exposure to the air remains firm and compact and stands shipping without breaking down. It produces no clinker and leaves on burning a small bulk

of red-white or reddish ash. Samples taken from surface prospects and placed in air-tight cans soon lose their bright luster, and the surface becomes covered with a velvety brown coating, which is no doubt due to the alteration of the weathered coal. The chief impurities of the coal are the sulphur balls and small lenses of pyrite that are scattered somewhat irregularly through the bed.

The higher coals are also distinctly black, with a bright luster as they come from the mine. They show more traces of iron stain and contain considerable gypsum and salt flakes in the joints or bedding planes. On exposure to the air they alter more readily than the lower Mesaverde coals, lose their bright luster, and become a dull black. In breaking down cracks form along the bedding planes and at right angles to them, producing somewhat regular blocks instead of the irregular pieces resulting from conchoidal fracture. The coals resemble somewhat the Adaville coals of Uinta County, but seem to be affected less on exposure to the air. The fractures and joints are more regular and cubical, and are quite different from the conchoidal fracture of the Adaville coals.

CHEMICAL PROPERTIES.

METHOD OF SAMPLING.

Representative samples of coal were collected throughout the field from the four coal groups, wherever good coal could be obtained, and were sent in air-tight cans to the chemical laboratory of the fuel-testing plant at Pittsburg, Pa., where they were analyzed under the direction of F. M. Stanton.

In order that the results from the samples collected might be entirely comparable, all sampling was done in accordance with the general plan adopted by the fuel-testing plant and described on pages 12-13 of this report.

ANALYSES OF COALS.

The accompanying table gives the result of analysis of samples as received in the laboratory, containing all the moisture, and the result expressed in terms of the air-dried sample—that is, one lacking the moisture which in that particular sample—under the conditions of the analysis, was lost in air drying. The analyses are grouped according to the geologic age of the bed sampled and arranged according to the calorific values, the highest coals heading the list for each group.

Analyses of coal samples from the Rock Springs field, Wyoming.

[F. M. Stanton, chemist in charge.]

Name of formation.....		Lower part of Mesaverde.									
Name of coal group.....		Rock Springs.									
Laboratory No.....		5365.	5926.	5364.	5366.	5785.	5806.	5928.	5695.	5786.	5805.
Sample as received:											
Prox.	Moisture.....	10.46	10.55	9.01	9.75	10.23	13.65	12.70	13.67	14.63	13.59
	Volatile matter.....	36.41	34.79	35.75	34.32	34.11	34.83	32.82	32.43	34.14	34.99
	Fixed carbon.....	50.90	50.42	52.61	52.50	51.10	50.08	49.94	51.00	47.69	48.12
	Ash.....	2.23	4.24	2.63	3.43	4.56	1.44	4.54	2.90	3.54	3.30
	Sulphur.....	.87	.86	.75	1.00	1.15	.98	.76	.72	1.01	1.02
Ult.	Hydrogen.....	5.37	5.66	.....	5.77	5.77	6.05	5.81	5.83	5.81	5.89
	Carbon.....	68.98	67.12	.....	68.39	66.87	64.53	65.14	65.93	63.45	64.12
	Nitrogen.....	1.32	1.27	.....	1.22	1.49	1.18	1.12	1.19	1.33	1.27
	Oxygen.....	21.23	20.85	.....	20.19	20.16	25.82	22.63	23.43	24.86	24.40
	Calories.....	6,817	6,756	6,868	6,810	6,682	6,590	6,512	6,424	6,321	6,396
British thermal units.....		12,271	12,161	12,362	12,258	12,028	11,862	11,722	11,563	11,378	11,513
Loss of moisture on air drying		4.00	4.80	2.70	3.50	5.00	4.90	5.60	6.30	6.00	5.30
Air-dried sample:											
Prox.	Moisture.....	6.73	6.04	6.49	6.48	5.51	9.20	7.52	7.87	9.18	8.75
	Volatile matter.....	37.93	36.54	36.74	35.56	35.90	36.63	34.77	34.61	36.32	36.96
	Fixed carbon.....	53.02	52.96	54.07	54.42	53.79	52.66	52.90	54.43	50.73	50.81
	Ash.....	2.32	4.46	2.70	3.54	4.80	1.51	4.81	3.09	3.77	3.48
	Sulphur.....	.91	.90	.77	1.04	1.21	1.03	.80	.77	1.07	1.08
Ult.	Hydrogen.....	5.14	5.39	.....	5.58	5.48	5.79	5.50	5.48	5.47	5.60
	Carbon.....	71.85	70.50	.....	70.87	70.39	67.86	69.00	70.36	67.50	67.71
	Nitrogen.....	1.37	1.33	.....	1.27	1.57	1.24	1.19	1.27	1.41	1.34
	Oxygen.....	18.41	17.42	.....	17.70	16.55	22.57	18.70	19.03	20.78	20.79
	Calories.....	7,101	7,097	7,058	7,057	7,034	6,929	6,898	6,856	6,724	6,754
British thermal units.....		12,782	12,774	12,704	12,703	12,661	12,473	12,417	12,340	12,104	12,157
Ratios—											
C ÷ H.....		13.96	13.09	.....	12.70	12.79	11.71	12.52	12.81	12.32	12.10
C ÷ (O + Ash).....		3.43	3.22	.....	3.31	3.29	2.81	2.94	3.18	2.75	2.79
Thickness of coal.....			<i>Ft. in.</i> 6 6	<i>Ft. in.</i> 12	<i>Ft. in.</i> 6 3	<i>Ft. in.</i> 6	<i>Ft. in.</i> 6	<i>Ft. in.</i> 6 11	<i>Ft. in.</i> 8	<i>Ft. in.</i> 8	<i>Ft. in.</i> 4 9
Name of formation.....		Lower part of Mesaverde.									
Name of coal group.....		Rock Springs.									
Laboratory No.....		5358.	5598.	5596.	5360.	5694.	5362.	5359.	5361.	5696.	5363.
Sample as received:											
Prox.	Moisture.....	8.53	13.76	13.15	13.01	13.01	13.51	9.76	14.51	16.02	14.43
	Volatile matter.....	35.60	31.52	33.07	34.00	32.83	33.62	32.62	34.17	33.63	33.30
	Fixed carbon.....	50.39	50.52	48.87	49.80	51.56	49.17	48.58	47.24	47.60	47.10
	Ash.....	5.48	4.20	4.91	3.19	2.60	3.70	9.04	4.08	2.75	5.17
	Sulphur.....	.78	1.30	1.15	.75	.71	1.46	.90	1.02	.94	.99
Ult.	Hydrogen.....	5.36	5.70	.....	5.91	5.25	.....	5.52	.....	6.11	5.55
	Carbon.....	66.15	63.78	.....	64.92	64.54	.....	63.76	.....	62.29	61.47
	Nitrogen.....	1.19	1.09	.....	1.20	1.20	.....	1.12	.....	1.08	1.14
	Oxygen.....	21.04	23.93	.....	24.03	25.70	.....	19.66	.....	26.83	25.68
	Calories.....	6,574	6,348	6,311	6,403	6,292	6,271	6,280	6,167	6,027	6,086
British thermal units.....		11,833	11,426	11,360	11,525	11,326	11,288	11,304	11,101	10,849	10,955
Loss of moisture on air drying		2.30	5.50	5.40	3.40	4.30	3.80	2.80	4.10	6.20	4.20
Air-dried sample:											
Prox.	Moisture.....	6.37	8.74	8.19	9.95	9.10	10.09	7.16	10.85	10.47	10.68
	Volatile matter.....	36.44	33.35	34.96	35.20	34.30	34.95	33.56	35.63	35.85	34.76
	Fixed carbon.....	51.58	53.46	51.66	51.55	53.88	51.11	49.98	49.26	50.75	49.16
	Ash.....	5.61	4.45	5.19	3.30	2.72	3.85	9.30	4.26	2.93	5.40
	Sulphur.....	.80	1.38	1.22	.78	.74	1.52	.93	1.06	1.00	1.03
Ult.	Hydrogen.....	5.22	5.38	.....	5.72	4.99	.....	5.36	.....	5.78	5.30
	Carbon.....	67.71	67.49	.....	67.21	67.44	.....	65.60	.....	66.41	64.17
	Nitrogen.....	1.22	1.15	.....	1.24	1.25	.....	1.15	.....	1.15	1.19
	Oxygen.....	19.44	20.15	.....	21.75	22.86	.....	17.66	.....	22.73	22.91
	Calories.....	6,729	6,717	6,671	6,628	6,575	6,519	6,461	6,430	6,425	6,353
British thermal units.....		12,111	12,091	12,008	11,931	11,835	11,733	11,630	11,575	11,566	11,435
Ratios—											
C ÷ H.....		12.95	12.52	.....	11.75	13.50	.....	12.22	.....	11.22	12.10
C ÷ (O + Ash).....		2.70	2.73	.....	2.68	2.62	.....	2.34	.....	2.60	2.27
Thickness of coal.....		<i>Ft. in.</i> 6 11	<i>Ft. in.</i> 8	<i>Ft. in.</i> 7 4	<i>Ft. in.</i> 5 9	<i>Ft. in.</i> 6	<i>Ft. in.</i> 6 9	<i>Ft. in.</i> 5 4	<i>Ft. in.</i> 7 7	<i>Ft. in.</i> 10 10	<i>Ft. in.</i> 2 5

Analyses of coal samples from the Rock Springs field, Wyoming—Continued.

Name of formation.....		Lower part of Mesaverde.									
Name of coal group.....		Rock Springs.									
Laboratory No.....		5698.	5697.	6043.	5370.	5369.	5368.	5357.	5373.	5699.	5812.
Sample as received:											
Prox.	Moisture.....	13.81	13.63	18.35	17.71	21.22	14.00	10.94	13.69	17.38	22.93
	Volatile matter.....	31.72	31.65	31.55	28.17	33.30	37.83	30.80	38.28	35.09	33.69
	Fixed carbon.....	49.50	48.78	48.46	51.80	43.80	45.00	42.70	44.61	43.47	39.35
	Ash.....	4.97	5.94	1.64	2.32	1.68	3.17	15.56	3.42	4.06	4.03
Ult.	Sulphur.....	.88	.78	.52	.64	.32	.48	1.01	.59	.87	.74
	Hydrogen.....	5.77	5.48	5.49	.....	5.56	.....	4.83	4.73	.....	5.61
	Carbon.....	61.92	61.31	57.37	.....	54.42	.....	53.95	55.13	.....	48.71
	Nitrogen.....	1.14	1.33	1.23	.....	1.11	.....	.87	1.24	.....	1.26
Oxygen.....		25.32	25.16	33.75	.....	36.91	.....	23.78	34.89	.....	39.65
Calories.....		5,996	5,850	5,374	5,446	5,028	5,151	5,214	4,937	4,633	4,416
British thermal units.....		10,793	10,530	9,673	9,803	9,050	9,272	9,385	8,887	8,339	7,949
Loss of moisture on air drying		4.90	5.00	12.50	6.10	12.30	3.50	1.50	2.70	5.30	8.00
Air-dried sample:											
Prox.	Moisture.....	9.37	9.08	6.69	12.36	10.17	10.88	9.58	11.30	12.76	16.23
	Volatile matter.....	33.35	33.32	36.06	30.00	37.97	39.20	31.27	39.34	37.05	36.62
	Fixed carbon.....	52.05	51.35	55.38	55.17	49.94	46.63	43.35	45.85	45.90	42.77
	Ash.....	5.23	6.25	1.87	2.47	1.92	3.29	15.80	3.51	4.29	4.38
Ult.	Sulphur.....	.92	.82	.59	.68	.36	.50	1.03	.61	.92	.80
	Hydrogen.....	5.50	5.18	4.69	.....	4.78	.....	4.73	4.55	.....	5.13
	Carbon.....	65.11	64.54	65.57	.....	62.05	.....	54.77	56.66	.....	52.95
	Nitrogen.....	1.20	1.40	1.41	.....	1.27	.....	.88	1.28	.....	1.37
Oxygen.....		22.04	21.81	25.87	.....	29.62	.....	22.79	33.39	.....	35.37
Calories.....		6,305	6,158	6,142	5,800	5,733	5,338	5,293	5,074	4,892	4,800
British thermal units.....		11,349	11,084	11,055	10,440	10,319	9,608	9,528	9,134	8,806	8,640
Ratios—											
C + H.....		11.83	12.42	13.98	.....	12.96	.....	11.57	12.46	.....	10.19
C + (O + Ash).....		2.38	2.22	2.37	.....	1.97	.....	1.42	1.54	.....	1.33
Thickness of coal.....		<i>Ft. in.</i> 8 6	<i>Ft. in.</i> 6 9	.....	<i>Ft. in.</i> 4	<i>Ft. in.</i> 3	<i>Ft. in.</i> 7 10	<i>Ft. in.</i> 3 2	<i>Ft. in.</i> 3 6	<i>Ft. in.</i> 5 4	<i>Ft. in.</i> 1 7
Name of formation.....		Lower part of Mesaverde.						Upper part of Mesaverde.			
Name of coal group.....		Rock Springs.						Almond.			
Laboratory No.....		5372.	5371.	5813.	5376.	5814.	5809.	6042.	5804.	5353.	5351.
Sample as received:											
Prox.	Moisture.....	16.39	28.01	27.38	26.82	29.50	33.79	13.14	14.75	13.34	16.01
	Volatile matter.....	36.78	32.04	30.34	33.42	30.59	29.35	30.61	31.98	36.54	35.02
	Fixed carbon.....	38.62	36.06	37.74	35.61	35.16	30.71	51.88	48.99	41.59	44.58
	Ash.....	8.21	3.89	4.54	4.15	4.75	6.15	4.37	4.28	8.53	4.39
Ult.	Sulphur.....	.95	.70	.77	.37	.37	.64	.42	.43	.46	.76
	Hydrogen.....	4.79	.....	5.81	5.39	5.86	5.86	5.48	5.05	4.45	5.04
	Carbon.....	50.09	.....	45.12	46.18	44.50	39.29	61.34	58.74	59.45	59.36
	Nitrogen.....	1.24	.....	1.26	1.00	1.10	1.16	1.35	1.12	1.13	1.19
Oxygen.....		34.72	.....	42.50	42.91	43.42	46.90	27.04	30.38	25.98	29.26
Calories.....		4,511	3,963	4,103	4,001	3,772	3,356	5,864	5,478	5,632	5,474
British thermal units.....		8,120	7,133	7,385	7,202	6,790	6,042	10,555	9,860	10,138	9,853
Loss of moisture on air drying		4.90	15.90	9.50	8.70	10.90	12.20	6.10	4.80	.90	2.40
Air-dried sample:											
Prox.	Moisture.....	12.08	14.40	19.76	19.85	20.88	24.59	7.50	10.45	12.55	13.94
	Volatile matter.....	38.68	38.10	33.52	36.61	34.33	33.43	32.60	33.59	36.87	35.88
	Fixed carbon.....	40.61	42.88	41.70	39.00	39.46	34.98	55.25	51.46	41.97	45.68
	Ash.....	8.63	4.62	5.02	4.54	5.33	7.00	4.65	4.50	8.61	4.50
Ult.	Sulphur.....	1.00	.83	.85	.41	.41	.73	.45	.45	.46	.78
	Hydrogen.....	4.47	.....	5.25	4.84	5.22	5.13	5.11	4.75	4.39	4.89
	Carbon.....	52.67	.....	49.86	50.58	49.94	44.75	65.33	61.70	59.99	60.82
	Nitrogen.....	1.30	.....	1.39	1.10	1.24	1.32	1.44	1.17	1.14	1.22
Oxygen.....		31.93	.....	37.63	38.53	37.86	41.07	23.02	27.43	25.41	27.79
Calories.....		4,743	4,712	4,534	4,382	4,233	3,822	6,245	5,754	5,683	5,609
British thermal units.....		8,538	8,482	8,060	7,888	7,620	6,881	11,241	10,357	10,230	10,095
Ratios—											
C + H.....		11.78	.....	10.59	10.42	9.56	8.71	14.64	12.99	13.66	12.44
C + (O + Ash).....		1.43	.....	1.30	1.17	1.15	.93	1.95	1.93	1.81	1.88
Thickness of coal.....		<i>Ft. in.</i> 4 8	<i>Ft. in.</i> 3 10	<i>Ft. in.</i> 4	<i>Ft. in.</i> 5	<i>Ft. in.</i> 3 6	<i>Ft. in.</i> 2 4	<i>Ft. in.</i> 6 4	<i>Ft. in.</i> 5	<i>Ft. in.</i> 4 10	<i>Ft. in.</i> 6 4

Analyses of coal samples from the Rock Springs field, Wyoming—Continued.

Name of formation.....		Upper part of Mesaverde.								(?)	
Name of coal group.....		Almond.								Black Buttes.	
Laboratory No.....		5352.	5347.	5950.	5597.	5599.	5348.	5349.	5350.	5951.	5952.
Sample as received:											
Prox.	Moisture.....	16.61	13.27	12.28	25.70	23.56	23.03	11.49	26.26	13.92	12.85
	Volatile matter.....	30.24	18.89	31.92	27.70	30.20	29.11	33.28	32.13	29.50	30.36
	Fixed carbon.....	43.96	58.82	47.09	40.69	40.75	41.60	43.51	37.47	52.49	52.48
	Ash.....	9.19	9.02	8.71	5.91	5.49	6.26	11.72	4.14	4.09	4.31
Ult.	Sulphur.....	.68	.96	.57	.29	.33	.53	.62	.39	.52	.56
	Hydrogen.....	5.28			5.17		5.23		5.46		5.21
	Carbon.....	55.64			49.10		50.45		47.16		60.27
	Nitrogen.....	1.10			1.07		1.15		1.23		1.47
Ult.	Oxygen.....	28.11			38.46		36.38		41.62		28.18
	Calories.....	5,230	5,276	4,978	4,331	4,267	4,475	4,679	4,067	5,776	5,877
	British thermal units.....	9,414	9,497	8,960	7,796	7,681	8,055	8,422	7,321	10,397	10,579
Loss of moisture on air drying.....		2.80	1.60	4.20	10.70	9.30	4.70	.20	11.70	6.20	3.60
Air-dried sample:											
Prox.	Moisture.....	14.21	11.86	8.43	16.80	15.72	19.23	11.31	16.49	8.23	9.60
	Volatile matter.....	31.11	19.20	33.32	31.02	33.30	30.55	33.35	36.39	31.45	31.49
	Fixed carbon.....	45.22	59.77	49.16	45.56	44.93	43.65	43.60	42.43	55.96	54.44
	Ash.....	9.46	9.17	9.09	6.62	6.05	6.57	11.74	4.69	4.36	4.47
Ult.	Sulphur.....	.70	.98	.60	.32	.36	.55	.62	.44	.55	.58
	Hydrogen.....	5.11			4.46		4.94		4.71		4.99
	Carbon.....	57.24			54.98		52.94		53.41		62.52
	Nitrogen.....	1.13			1.20		1.21		1.39		1.53
Ult.	Oxygen.....	26.36			32.42		33.79		35.36		25.91
	Calories.....	5,381	5,362	5,196	4,850	4,705	4,696	4,688	4,606	6,158	6,096
	British thermal units.....	9,685	9,651	9,353	8,730	8,469	8,452	8,439	8,291	11,084	10,974
Ratios—											
C÷H.....		11.20			11.97		10.71		11.33		12.50
	C÷(O+Ash).....	1.61			1.37		1.29		1.32		2.09
Thickness of coal.....		<i>Ft. in.</i> 5 1	<i>Ft. in.</i> 6	<i>Ft. in.</i> 6	<i>Ft. in.</i> 7 2	<i>Ft. in.</i> 7	<i>Ft. in.</i> 8	<i>Ft. in.</i> 6 ½	<i>Ft. in.</i> 4 6	<i>Ft. in.</i> 6 3	<i>Ft. in.</i> 5 6

Name of formation.....		(?)				Wasatch.					
Name of coal group.....		Black Buttes.				Black Rock.					
Laboratory No.....		5808.	5811.	5810.	5930.	5803.	5802.	5374.	5375.	5367.	
Sample as received:											
Prox.	Moisture.....	18.86	19.42	15.14	16.65	20.33	22.52	22.14	31.37	26.28	
	Volatile matter.....	29.17	31.02	32.58	29.15	31.43	30.83	31.34	29.60	31.28	
	Fixed carbon.....	47.85	45.02	47.88	49.56	43.03	41.83	41.85	28.91	26.23	
	Ash.....	4.12	4.54	4.40	4.64	5.21	4.82	4.67	10.12	16.21	
Ult.	Sulphur.....	.49	.51	.62	.28	.98	.96	.80	1.27	1.06	
	Hydrogen.....	5.64			5.45	5.92	5.82	5.55	5.43		
	Carbon.....	58.96			59.67	55.97	52.44	52.40	37.03		
	Nitrogen.....	1.45			1.08	1.12	.96	.93	.79		
Ult.	Oxygen.....	29.34			28.88	30.80	35.00	35.65	45.36		
	Calories.....	5,713	5,677	5,766	5,737	5,495	5,006	4,868	3,130	3,311	
	British thermal units.....	10,283	10,219	10,379	10,327	9,891	9,011	8,762	5,634	5,960	
Loss of moisture on air drying.....		5.80	6.10	3.70	6.10	9.70	10.70	12.50	14.20	6.90	
Air-dried sample:											
Prox.	Moisture.....	13.86	14.18	11.88	11.24	11.77	13.24	11.01	20.01	20.82	
	Volatile matter.....	30.97	33.04	33.83	31.04	34.81	34.52	35.82	34.50	33.60	
	Fixed carbon.....	50.80	47.94	49.72	52.78	47.65	46.84	47.83	33.70	28.17	
	Ash.....	4.37	4.84	4.57	4.94	5.77	5.40	5.34	11.79	17.41	
Ult.	Sulphur.....	.52	.54	.64	.30	1.09	1.08	.91	1.48	1.14	
	Hydrogen.....	5.31			5.08	5.36	5.18	4.76	4.49		
	Carbon.....	62.59			63.55	61.98	58.72	59.89	43.16		
	Nitrogen.....	1.54			1.15	1.24	1.08	1.06	.92		
Ult.	Oxygen.....	25.67			24.98	24.56	28.54	28.04	38.16		
	Calories.....	6,065	6,046	5,988	6,110	6,085	5,606	5,563	3,648	3,556	
	British thermal units.....	10,916	10,882	10,778	10,998	10,953	10,091	10,014	6,566	6,402	
Ratios—											
C÷H.....		11.78			12.48	11.56	11.34	12.31	9.58		
	C÷(O+Ash).....	2.09			2.12	2.09	1.73	1.75	.86		
Thickness of coal.....		<i>Ft. in.</i> 6 6	<i>Ft. in.</i> 4 6	<i>Ft. in.</i> 5 6	<i>Ft. in.</i> 21	<i>Ft. in.</i> 8 6	<i>Ft. in.</i> 8 6	<i>Ft. in.</i> 5 6	<i>Ft. in.</i> 4	<i>Ft. in.</i> 1 6	

5365. Rock Springs; sec. 11, T. 18 N., R. 105 W.	5371. Sec. 12, T. 21 N., R. 104 W.
5926. Superior; sec. 27, T. 21 N., R. 102 W.	5813. Sec. 23, T. 20 N., R. 102 W.
5364, 5366. Rock Springs; sec. 11, T. 18 N., R. 105 W.	5376. Sec. 34, T. 21 N., R. 104 W.
5785. Superior; sec. 28, T. 21 N., R. 102 W.	5814. Sec. 16, T. 20 N., R. 102 W.
5806. Gunn; sec. 8, T. 19 N., R. 104 W.	5809. Sec. 29, T. 20 N., R. 102 W.
5928. Superior; sec. 27, T. 21 N., R. 102 W.	6042. Rock Springs; sec. 22, T. 19 N., R. 105 W.
5695, 5786. Superior; sec. 20, T. 21 N., R. 102 W.	5804. Sec. 21, T. 23 N., R. 103 W.
5805. Gunn; sec. 8, T. 19 N., R. 104 W.	5353. Sec. 6, T. 22 N., R. 103 W.
5358. Rock Springs; sec. 35, T. 19 N., R. 105 W.	5351. Point of Rocks; sec. 26, T. 20 N., R. 101 W.
5598, 5596. Superior; sec. 20, T. 21 N., R. 102 W.	5352. Sec. 26, T. 20 N., R. 101 W.
5360. Rock Springs; sec. 25, T. 19 N., R. 105 W.	5347. Sec. 6, T. 22 N., R. 103 W.
5694. Sec. 5, T. 21 N., R. 103 W.	5950. Sec. 6, T. 22 N., R. 103 W.
5362. Rock Springs; sec. 25, T. 19 N., R. 105 W.	5597. Sec. 10, T. 21 N., R. 102 W.
5359. Rock Springs; sec. 26, T. 19 N., R. 105 W.	5599. Sec. 10, T. 21 N., R. 102 W.
5361. Rock Springs; sec. 25, T. 19 N., R. 105 W.	5348. Sec. 24, T. 22 N., R. 103 W.
5696. Sec. 3, T. 21 N., R. 103 W.	5349. Sec. 6, T. 22 N., R. 103 W.
5363. Rock Springs; sec. 25, T. 19 N., R. 105 W.	5350. Sec. 34, T. 22 N., R. 104 W.
5698. Sec. 3, T. 21 N., R. 103 W.	5951. Sec. 31, T. 19 N., R. 100 W.
5697. Sec. 9, T. 21 N., R. 103 W.	5952. Sec. 16, T. 18 N., R. 100 W.
6043. Superior; sec. 20, T. 21 N., R. 102 W.	5808, 5811. Black Buttes; sec. 20, T. 18 N., R. 100 W.
5370. Sec. 23, T. 21 N., R. 104 W.	5810. Sec. 31, T. 19 N., R. 100 W.
5369. Sec. 10, T. 21 N., R. 104 W.	5930. Sec. 28, T. 19 N., R. 100 W.
5368. Sec. 14, T. 21 N., R. 104 W.	5803. Sec. 24, T. 23 N., R. 104 W.
5357. Rock Springs; sec. 26, T. 19 N., R. 105 W.	5802. Sec. 24, T. 23 N., R. 104 W.
5373. Sec. 34, T. 21 N., R. 104 W.	5374. Sec. 29, T. 21 N., R. 104 W.
5699. Sec. 8, T. 21 N., R. 103 W.	5375. Sec. 17, T. 21 N., R. 104 W.
5812. Sec. 18, T. 20 N., R. 102 W.	5367. Sec. 30, T. 21 N., R. 104 W.
5372. Sec. 34, T. 21 N., R. 104 W.	

QUALITY OF COAL.

The analyses show that all samples collected from surface outcrops, as well as some collected from shallow or open prospect pits, give much lower values than samples collected from mines or more extensive prospects, where good unaltered samples of coal could be obtained. Although the coal obtained from prospect pits may seem firm and little altered, it seldom gives as good chemical results as samples obtained from the mines. Many analyses of weathered samples show approximately one-half the heat values obtained with mine samples from the Rock Springs coal group. On closer examination the coal clearly shows its weathered condition. From the various mine samples collected it appears that all the Rock Springs or lower Mesaverde coal falls in the bituminous class. The upper Mesaverde coal, or that of the Almond group, is physically and chemically more closely related to the coals of the Black Buttes and Black Rock groups than to the lower Mesaverde or Rock Springs coal. All the coals above the lower Mesaverde contain more moisture and are lighter in weight than those of that group, and slack considerably on exposure to the air. These coals fall in the subbituminous class, but on the whole are better than the Adaville and Evanston coals of southern Uinta County. The coals of the Rock Springs field have a low sulphur content, which ranges from 0.30 to 1.52, but is usually less than 1 per cent. They are comparatively clean coals and have a low content of ash.

The following statement may be considered as representing the beds of these four coal groups:

Values of coal in the Rock Springs coal field, Wyoming.

Coal group.	Number of samples.	Range.	Ash.	Sulphur.	Carbon.	Fixed carbon.
Rock Springs.....	36	Maximum.....	15.80	1.52	71.85	55.17
		Minimum.....	1.51	.36	44.75	31.58
		Average.....	4.60	.96	62.91	48.59
Almond.....	12	Maximum.....	11.74	.96	65.32	59.98
		Minimum.....	4.50	.32	52.94	41.97
		Average.....	7.11	.56	57.94	47.24
Black Buttes.....	5	Maximum.....	4.84	.64	62.59	55.96
		Minimum.....	4.36	.52	62.59	47.94
		Average.....	4.52	.56	62.55	51.77
Black Rock.....	6	Maximum.....	17.41	1.48	63.55	52.78
		Minimum.....	4.94	.30	43.16	28.17
		Average.....	8.44	1.00	57.46	42.83

On computing the carbon-hydrogen ratio^a for the analyses given in the table on pages 270-272, it will be found that there is a great irregularity in the order of the heat values of the coal as given by this ratio and the actual determined British thermal unit values, the difference on many samples being from 1,500 to 2,500 British thermal units. The carbon-hydrogen ratio apparently bears no regular relation to the heat values of the coal. On the other hand, a comparative study of ultimate analyses shows that in nearly all kinds of coals the ash and oxygen are of nearly equal importance as impurities from the standpoint of heat efficiencies. On computing the carbon-oxygen ratios and arranging the values according to the ratio $C \div (O + \text{ash})$,^b it is found that these values have approximately the same order as the efficiencies determined calorimetrically. Although the order differs slightly from the British thermal unit values, the difference is small, being for the greater number of samples less than 100 and seldom exceeding 300 British thermal units. The only notable exception is No. 6042 of the table, where the ratio $C \div (O + \text{ash})$ places the coal approximately 900 British thermal units lower than the calorimetrically determined value. Many of these coals are greatly weathered, and it is remarkable that these ratios should correspond so closely with the actual determined British thermal unit values. It appears that the ratio $C \div (O + \text{ash})$ furnishes a fairly satisfactory basis for classifying or grouping the coals according to their heat efficiencies.

COMPARATIVE VALUES.

The lower Mesaverde or Rock Springs coals occur in the same geologic formation as the high-grade coals of the Yampa, Danforth Hills, and Grand Hogback fields of Colorado, and the Book Cliffs field of Utah, and compare favorably with them. These coals are not so good as the coals of Benton age in Uinta County, which show a tendency to coke and have a higher heating efficiency. The Rock

^a Campbell, M. R., The classification of coals: Trans. Am. Inst. Min. Eng., vol. 36, 1905, p. 324; Prof. Paper U. S. Geol. Survey No. 48, 1896, pp. 156-173.

^b White, David, Oxygen values and coal alteration; Science, new ser. vol. 27, 1908, p. 537.

Springs coal, as a locomotive fuel or steam coal, has few superiors in the West. It operates under a forced draft without heavy sparking and is a quick steamer, leaving but little ash. In this respect it differs decidedly from some of the "Upper Laramie" coals of Carbon County and from the coals in Montana and northern Wyoming in the vicinity of Sheridan, Wyo. At Dana and Carbon the coal is so light that in the forced draft of a railroad locomotive it nearly all goes out of the smokestack, covering the cars with showers of sparks and causing many disastrous fires. However, by means of special grates, coal of this character can be used for locomotives, and the Hanna and Sheridan coals are extensively and satisfactorily used at present in the locomotives of the Union Pacific and Burlington railroads, respectively. Although the coal is very light for such work, it has proved very successful when used under natural draft for heating purposes, and has developed a large trade.

The coals of the Almond, Black Buttes, and Black Rock groups, although very little used at present, are no doubt much like the "Upper Laramie" coals of the Hanna field.^a

HISTORY OF DEVELOPMENT.

Coal has been known in this region since the early explorations of the United States Engineering Corps during the first part of the nineteenth century. Actual mining, however, did not begin until the building of the Union Pacific Railroad across Wyoming in 1868, and from that time until 1900 all the mining camps within this area have been located on the main line of the Union Pacific in Bitter Creek valley. In 1900 a branch was built from the main line up Horsethief Canyon to the Superior mining camp, this being the first and only mining locality opened more than a mile away from the main line. Mines in this region have been opened at Rock Springs, Superior, Point of Rocks, Hallville, and Black Buttes.

ROCK SPRINGS.

One of the first mines opened in the vicinity of Rock Springs was the old Van Dyke mine, about 2 miles east of the town. This mine was opened in 1868. There are three coal beds here, but only the lower one, 3 feet 10 inches to 4 feet thick, was worked. The mine was soon abandoned and other mines were opened farther west.

In Rock Springs there are a large number of coal beds, many of which have not been opened. Besides the thicker beds there are an indefinite number of smaller ones, from 3 feet to a fraction of an inch thick. Mines have been opened on six of the coal beds in the immediate vicinity of the town. These six beds are locally known, from the base upward, as the Van Dyke, No. 7, No. 1, No. 3, No. 5, and

^a Veatch, A. C., Coal fields of east-central Carbon County, Wyo.; Bull. U. S. Geol. Survey No. 316, 1907, pp. 253-259.

No. 6 beds. The old Van Dyke mine was located on the bed of the same name; the Union Pacific Coal Company's mines Nos. 7, 8, 9, and 10 and the Central Coal and Coke Company's mines Nos. 1, 2, 3, 4, and 5 are all located on No. 7 bed; the Union Pacific Coal Company's mine No. 1 and old mines Nos. 2 and 4 on No. 1 bed; the Union Pacific Coal Company's mines Nos. 3 and 5 on No. 5 bed, and old mine No. 6 on No. 6 bed. All the mines on these coal beds, except those on Nos. 1 and 7, have been abandoned for some time. Only one mine—No. 1 of the Union Pacific Coal Company—is at present working No. 1 bed. All the other producing mines of the Union Pacific Coal Company, Nos. 7, 8, 9, and 10; and the Central Coal and Coke Company's two mines, Nos. 2 and 5 (the latter comprising what is left of mines Nos. 1, 3, and 4, as well as the new No. 5 slope), are working No. 7 bed, which furnishes a greater supply of coal than any other bed at Rock Springs. No. 1 mine of the Union Pacific Coal Company, which is the oldest and best-known working mine in this locality and produces some of the best coal, is at present $1\frac{1}{2}$ miles down the slope and working a breast of coal 3 miles long.

As Rock Springs does not lie within the area mapped the past summer, no further detailed description of the Rock Springs mines will be given in this paper, although they were all visited and samples of coal were collected for analysis at all of them. It should be stated, however, that two spur tracks are being built from the main line of the Union Pacific Railroad—one northward from Rock Springs up Killpecker valley, the other northward along the west side of Baxter basin from a point west of Baxter station to the Gunn mining camp, in T. 19 N., R. 104 W., where a new mine is being opened by the Gunn Mining Company.

BLACK BUTTES.

At Black Buttes a mine was opened soon after the extension of the Union Pacific Railroad into this region in 1868. Two beds of coal were worked at this place for some time. The upper bed is 4 feet thick; the main bed, 15 feet lower, has a thickness of 8 feet and supplied most of the coal while the mine was in operation. After a short period of activity the mine was abandoned, as better coal was obtained in the vicinity of Rock Springs.

In 1907 the Rock Springs-Gibraltar Coal Company opened a mine approximately 1 mile southwest of the old Black Buttes mine and on the same coal bed. This company is opening two coal beds at this place; the upper, 6 feet 6 inches thick, is the main bed, and 78 feet below this occurs a second bed 4 feet 6 inches thick, which is also being developed; 13 feet 8 inches below the second is another bed of good coal 2 feet 2 inches thick, which at present is not prospected.

HALLVILLE.

The old Hall mine, about 4 miles northwest of Black Buttes, on the west side of the railroad, was opened in 1868. Four beds of coal were discovered at this place. The upper bed, 4 feet 8 inches thick, near the surface, was never developed, as the coal was considered of inferior quality. A bed 5½ feet thick was worked to considerable extent. The third bed, 12 feet below the second, is 9 feet 8 inches thick, and a still lower bed is approximately 3 feet thick. This mine was worked for only a short time and was then abandoned.

In 1906 a mine was opened in a Black Rock coal bed east of the railroad, in sec. 28, T. 19 N., R. 100 W., by the Sioux City-Rock Springs Mining Company. This mine is south of a large fault, which here as well as at the old Hall mine carries the beds on the south side several miles to the west. The company soon became involved in litigation and all development work was abandoned.

POINT OF ROCKS.

As early as 1868 the Union Pacific Railroad Company opened a mine at Point of Rocks and built a spur to it from the main line. In the hill at this place five coal beds occur within a vertical height of 80 feet; the lowest is approximately 100 feet above the bed of the creek. The mine was operated for a short time and then abandoned, as better coal was obtained at Rock Springs.

During the summer of 1907 the Rock Springs and Wyoming Coal Company reopened this mine, built a new spur track from the main line, and expected to ship coal by January 1, 1908. Two beds are worked at present, the upper being 6 feet 4 inches and the lower 5 feet 1 inch thick; between these two occurs a third or middle bed, about 4 feet 4 inches thick.

SUPERIOR.

The work of opening the Superior mines was started early in 1906. Considerable prospecting had been carried on in this region before this time, but no mining was attempted until the Superior branch of the Union Pacific Railroad was built up Horsethief Canyon. Acknowledgment is due to Superintendent Frank A. Manley and Assistant Superintendent W. D. Brennan, of the Superior Coal Company, for the information on which the following description of the four mines at this place is based.

"A" MINE.

The "A" mine consists of drift and slope openings on No. 7 bed and a drift opening on No. 1 bed, which is about 2,500 feet farther up the canyon and 250 feet vertically above No. 7 bed. Work was begun February 3, 1906, and the first coal shipped October 6, 1906. The daily output at present is 600 tons.

The drift on No. 7 bed is driven on the strike of the bed and is 1,600 feet in length, running under a hill from one canyon to the next, and open at both ends. The rooms, 200 to 600 feet in length, depending on the distance to the outcrop, are driven at right angles directly up the rise, which is about 4° . They are 40 feet between centers and 24 feet wide, with a 10-foot pillar, which is left until the rooms are finished and brought back, allowing the roof to cave. The coal bed is from 6 feet to 6 feet 5 inches thick, and is undermined and shot down.

The slope opening on No. 7 bed is 1,200 feet long and has an average pitch of 4° N. 61° E. Coal is hoisted out by cable in cars of 3,500 pounds capacity. It is a fair blacksmithing coal and gives a reddish ash without clinker. Large horses are used for hauling cars on entries and up into the rooms. The mine is ventilated by furnace and has no water or gas. Timber is used in the rooms to keep up the roof until the pillars are brought back. The roof is a sandy shale and is regular throughout the mine. The floor is composed of shale. The coal bed is clean and ranges in thickness from 6 feet to 6 feet 6 inches.

The opening on No. 1 bed is 600 feet long and is similar to the drift on No. 7 bed. The coal bed is 8 feet thick, with a 2-inch band of bone about 1 foot 6 inches from the roof. Cars handling the coal from this opening go to the same dump that handles the coal from No. 7 bed.

"B" MINE.

Work on the "B" mine started in April, 1906. The drift, now 3,000 feet in length, followed the strike of a very thin bed of coal which widened out to about $6\frac{1}{2}$ feet at the point reached in July, 1907, when shipping began. The coal was dirty and not workable for the first 1,800 feet; beyond that point there is from 7 to 8 feet of clean coal overlying a shale floor. The coal is the same as that at the lower openings of the "A" mine and is mined and hauled in the same way, the average daily output being about 200 tons. It is necessary to timber the mine, as the roof is a sandy shale that will not stay up on more than 10-foot spans.

"C" MINE.

Work on the slope of the "C" mine, which is located on No. 1 bed, was started February 7, 1906, in coal having thick bands of shale, but no coal was shipped until December of the same year. The slope is 1,650 feet in length and has an average pitch of 4° N. 37° E. The room and pillar system is employed, the rooms being driven up the rise as at "A" mine. Timbers are used in all rooms and in entries where the roof is shale. A coal roof is left in many of the entries. The coal is undermined and all shot down in the rooms, then hauled by horse along the entries to the slope, where it is hoisted by cable in cars of 3,500 pounds capacity. The daily output averages about

700 tons. The mine is ventilated by an exhaust fan and provided with electric signals throughout. The coal is considered a good smithing coal, but does not coke. It burns with a white ash and leaves no clinker. The bed of coal is from 7 feet 6 inches to 9 feet thick, with a band of bone 1 inch to 1 foot thick about 2 feet from the roof.

"D" MINE.

The "D" mine was opened April 19, 1906, and late in the same year closed down; mining was resumed in June, 1907, and continued until February 1, 1908, when the mine was again closed. This mine is a drift opening on No. 1 bed, 1,200 feet long, driven on the strike of the coal. The coal is the same as in the "C" mine. It is undermined and all shot down at once and is hauled to the dump in the same way as at "A" mine. The same system of mining and ventilating is used as at the "A" and "B" mines. The rooms are timbered and in the entries a coal roof is left. The output was about 300 tons per day.

ECONOMIC CONSIDERATIONS.

MINING OPERATIONS.

Up to the present time coal-mining operations in Sweetwater County have been conducted chiefly by the Union Pacific Coal Company. At present this company operates almost wholly for the purpose of supplying coal to the Union Pacific Railroad. At Rock Springs the Central Coal and Coke Company has been mining coal for commercial markets since 1889. In 1868 Rock Springs produced 365 tons of coal, while in 1906 the yearly output of the mines was over 2,100,000 tons. The Superior mines began shipping coal in 1906, and the output for the year was, in round numbers, 12,000 tons. In 1907 the daily output of the four mines was 1,800 tons, making a probable annual production of 500,000 to 600,000 tons. The shipments of coal from other localities in this field have been meager and never exceeded a few hundred tons per day. Mines at present are being opened in the vicinity of Point of Rocks and Black Buttes, and in the future these coals may be mined much more extensively.

The entire region from Rock Springs northward around the north end of the dome is a valuable field of bituminous and subbituminous coal. In all parts of the coal zones there are several coal beds that will be profitable to mine. Coal is the chief mineral product of Wyoming, and Sweetwater County heads the list of all the counties as a coal producer. Uinta County is a close second, and in 1906 produced 2,078,772 tons, as compared with Sweetwater County's output of 2,121,546 tons, all of which came from the Rock Springs field. In 1903 these two counties produced 78 per cent of the coal output of the State and employed 69 per cent of the miners; in 1906 they produced

68 per cent of the coal yield of the State and employed 67 per cent of the miners. In the same year (1906) the Rock Springs field produced 34 per cent of the State's entire coal output and employed 30 per cent of the miners. Practically all the coal in this field is mined under contract at a definite rate per ton, established by an agreement between the operators and the miners' union.

Most of the mining in this field will no doubt be carried on by slopes from the outcrop, although in places it may be found advantageous to sink shafts, particularly along the valleys some distance back from the outcrop, where several hundred feet of overlying Tertiary beds have been removed. The room and pillar system prevails throughout the field, and as a rule the pillars are not pulled at present. Mining of the coal is generally done by shooting off the solid face of the bed. Undercutting by hand and machine is employed in some of the mines. Haulage from the rooms is effected by horse and mule, and in the main slope or gangway either by mules or cable. Some of the mines at Rock Springs are equipped with electric motors, and all are supplied with a complete mine telephone system. Ventilation in the mines is accomplished by means of fans or furnaces. There is comparatively little gas, and accidents from this cause are relatively rare.

MINING CONDITIONS.

In opening new mines in this locality or in contemplating any future economic development among the factors that must be taken into consideration are transportation, timber supply, and water supply.

TRANSPORTATION.

As previously stated, all the producing mines, except those at Superior, are on the main line of the Union Pacific Railroad. This railroad cuts the Rock Springs coal field approximately in halves and is destined to control the development of the field. The grade along this line is moderate, and by short spur lines, also with moderate grade, similar to the Superior branch, it will be comparatively easy to reach all points at which mines may be opened to advantage.

TIMBER SUPPLY.

As far as the mines have been developed at present it appears that the roof and floor of the coal beds are firm and give but little trouble in mining. The mines are not dangerously gaseous and water has not proved particularly troublesome. In places part of the coal is left as roof in order to prevent caving of the shale. Timber is used extensively for props to support the roof until the pillars are drawn, and considerably increases the cost of mining. All timbers used in this field must be shipped in, as there is no timber in the region. The nearest sources of timber supply for this area are (1) the Uinta Forest

Reserve, south of the field; (2) the Teton Forest Reserve of northern Uinta County, where the timber could be floated down Hams Fork to Kemmerer, Wyo., and then shipped eastward by rail; (3) the mountain ranges on the east, including the Sierra Madre and the Ferris and Green mountains.

WATER SUPPLY.

This entire region is a desert. The only water available is that of Bitter Creek, and this is scant in amount and not fit for domestic use. The few isolated springs that are scattered over the region are located for the most part along fault lines. They furnish only a small quantity of water, and can not be depended on to supply even a small mining camp.

At Rock Springs the Bitter Creek water and water pumped from the mines is used to some extent for stock, but all water for domestic or household purposes is pumped from Green River. At Superior the water from a small spring is used in part for watering stock, but all the water used by the miners, as well as that used by the town, is shipped in large tanks by rail from Green River. Drilling for water is being conducted systematically at Superior, with the hope of getting an abundant supply of good artesian water from the sandstones of the Mesaverde formation. Flowing water was obtained in the valley just north of the depot while prospecting for coal was being carried on with a diamond drill. The water-bearing sandstone at this place gave promise of a source of water sufficient to meet the full demands of the mining camp. Considerable water was also obtained from the white sandstone of the Mesaverde in the vicinity of Emmons Cone, a few miles north of Superior.

It appears from the well records and flowing wells at Rock Springs, Superior, Bitter Creek, and other points along the Union Pacific Railroad that water can be obtained in almost any part of the Rock Springs field, outside of the Baxter basin, by drilling to considerable depths. Whether the supply will be large enough to meet the full demand of a mining camp can be determined only by careful and systematic drilling. In many parts of the field, particularly in the Great Divide Basin, water may be obtained by drilling to relatively shallow depths, say several hundred feet, but this water is very apt to be highly alkaline.

COAL MARKETS.

The natural commercial markets for coal from the Rock Springs field are the villages, towns, and cities lying to the east and west along the Union Pacific Railroad and the Oregon Short Line, with their various connecting lines and centers of industry. Coal from this field has been shipped east as far as Omaha, Kansas City, and St. Louis; and west to Salt Lake and other cities in the mountain States,

to Oregon and California. However, as stated before, most of the coal has been used by the railroad companies and only a small amount of the Rock Springs coal has found its way into commercial channels to compete successfully with coals from other localities; for example, with Interior Province Carboniferous coal at Omaha, with the Newcastle and Sheridan coal in the Black Hills, with the Colorado coal at Denver, and with Utah coal at Salt Lake and other western cities. At present all of the commercial Rock Springs coal goes west, the greater part of it to Salt Lake.

AMOUNT OF AVAILABLE COAL.

In computing the approximate amount of available coal in the portion of the Rock Springs field mapped last summer and discussed in this report, only those coal beds which are 2 feet 6 inches or more in thickness have been taken into consideration, although it is well known that bituminous coals 2 feet and less in thickness are being mined at present in Arkansas and other States. The average thickness of the beds may be obtained from the representative sections given under the discussion of the four coal groups. It is assumed that the average thickness of the coal bed as computed from the measurements made along the outcrop will hold equally well for the bed down the dip, as the present outcrop at an earlier stage of erosion represented the conditions along the dip at that place. From the analyses of the coal it appears that all the coal of the Rock Springs coal group belongs to the bituminous class, and that all the coal of the Almond, Black Buttes, and Black Rock groups belong to the sub-bituminous class. The density of these classes of coal is about 1.3. A bed of coal with a specific gravity of 1.3 and 1 foot thick will run approximately 1,123,000 tons per square mile, or, in round numbers, 1,800 tons per acre. Using this factor in the calculation and taking all coal beds 2 feet 6 inches or more in thickness to a depth of 1,500 feet below the surface, or approximately 200 feet less than the deepest mine worked at present at Rock Springs, gives for the Rock Springs field the following tonnage:

Bituminous coal.....	4,843,000,000
Subbituminous coal.....	41,477,873,000
	46,320,873,000

Using the same factors but extending the computation from the surface to a depth of 4,000 feet gives the following figures:

Bituminous coal.....	12,649,569,000
Subbituminous coal.....	58,688,926,000
	71,338,495,000

It should be borne in mind that these figures are only approximations, and the total amount may exceed these figures by as much as 50 per cent.

COAL FIELDS OF NORTHWESTERN COLORADO AND NORTHEASTERN UTAH.

By HOYT S. GALE.

INTRODUCTION.

NATURE OF THE PRESENT INVESTIGATION.

This paper is a preliminary statement of the results of work in the coal fields of northwestern Colorado and northeastern Utah during the summer of 1907.^a In 1905 a preliminary reconnaissance of the Yampa coal field, of Routt County, was made.^b In the summer of 1906 similar work was extended southwestward from the Yampa field, and the Danforth Hills and Grand Hogback coal fields, of Routt, Rio Blanco, and Garfield counties, were mapped.^c The work of the past season was a continuation of that of the two preceding years, extending the area studied westward through Routt and Rio Blanco counties, Colo., and including some less extensive coal fields in Uinta County, Utah, and southern Uinta County, Wyo.

ACCESSIBILITY.

At present these fields have no railroad connection, although surveys for several projected lines have recently been made into the region. Of these lines, the Denver, Northwestern and Pacific Railway ("Moffat road") is under active construction in the eastern part of Routt County and bids fair to push westward not far from the lower Yampa and White River fields in the near future. An extension of the Uintah Railway has been surveyed from Dragon to Vernal, Utah, crossing the projected route of the "Moffat road" near Green River. The Union Pacific Railroad has made a preliminary survey south from Rawlins, Wyo., intending to reach the Yampa Valley in the vicinity of Craig.

^a A more complete report combining the results of the preceding season's work in the Danforth Hills and Grand Hogback fields with those of last season's work as outlined here, together with detailed contour maps of the whole area, will be published as a separate bulletin of the Survey.

^b Fenneman, N. M., and Gale, H. S., The Yampa coal field, Routt County, Colo.: Bull. U. S. Geol. Survey No. 297, 1906.

^c Gale, H. S., The coal fields of the Danforth Hills and Grand Hogback, Colorado: Bull. U. S. Geol. Survey No. 316, 1907, pp. 264-301.

FIELD WORK.

Personnel.—The members of the field party engaged in geologic work throughout the season were John A. Davis, Charles W. Stoops, and the author. T. W. Stanton spent about three weeks with the party at the beginning of the season, for the purpose of collecting fossil evidence bearing on the age of the coal-bearing beds. W. H. Beekly and J. Sidney Heil rendered valuable assistance in the management of the camp and in the field work.

Methods and conditions.—This work was planned for the purpose of making a preliminary examination and classification of the public lands upon which valuable coal was supposed to exist, but about which very little authoritative information was available. Much of the field work was based on the recently established lines of the township resurveys in this part of Colorado. In each township or part of a township that contained coal, a large proportion of the section lines were retraced for the purpose of locating the coal. This was done with a pocket compass, the distances being measured by pacing and checked by the corners that were found along the lines. An average of about five working days for one man was devoted to each township, and this may serve as a rough measure of the detail that could be obtained in such a review of the area. In addition to this work meanders were made along roads and trails or in gulches and canyons for the purpose of examining the most favorably exposed geologic sections and procuring such additional data as could not be obtained by other methods.

In territory where the new surveys had not been completed it was necessary to pursue a method of traverse, for which both plane table and compass and notebook were used. In the absence of the constant checks on well-established land corners it was not possible to obtain so satisfactory a result as by the other method.

By far the greater part of the valuable coal is concealed at the surface, and its presence over much of the region can only be inferred from a study of the sections where it is better exposed. Individual beds can not be traced from place to place for any considerable distance without doing a great amount of development work along the outcrops, and indeed it is extremely doubtful if such work could ever be satisfactorily done in much of the field until all or most of the beds are actually opened in mining or have been prospected by the drill. More and more detailed examinations will doubtless become necessary from time to time as the development of the field progresses and the coal lands themselves become more valuable.

GEOLOGY.

STRATIGRAPHY.

SIGNIFICANCE OF THE ROCK FORMATIONS.

The deposits in which the coal was originally formed are a part of a great series of sedimentary strata that were laid down at a time when this part of the continent was largely submerged. The submergence probably ranged from deep sea to shallow water and swampy conditions, as well as from salt-water or marine to brackish and fresh water stages. These strata were deposited in an approximately horizontal position. Subsequent movements of the earth's crust have folded or even broken the originally continuous deposits, so that it is now necessary to study their attitude and order of superposition in order to explain the relations of one set of beds to another. Their position in the stratigraphic section indicates in a general way their relative geologic age, although there are also evidences that great time intervals have elapsed in which no deposits were being formed, or in which was being laid down material that was subsequently removed, leaving little or no record of its existence.

SUMMARY AND DESCRIPTION OF FORMATIONS.

The following table is a brief description of evidence that has been collected from this general region, but includes only that part of the stratigraphic column most directly related to a discussion of the coal-bearing rocks.

Rock formations of the northwestern Colorado coal fields.

Geologic age.	Formation.	Description of strata.	Topographic features.	Thickness.	Economic value.
Probably late Tertiary or younger.	"Browns Park" formation.	Consists of loose or slightly consolidated sandy material with local harder sandstone beds and some beds of gravel. Contains much calcareous material in the form of cement or filling between the quartz sand grains. Its color is everywhere chalky or limy white.	Forms low sand hills or valley country, commonly covered sparsely with sagebrush, greasewood, cedar, or piñon. Typically exposed in Axial Basin about Juniper Mountain, and supposed to extend continuously northwestward into Browns Park.	Not determined.	

Marked unconformity.

Rock formations of the northwestern Colorado coal fields—Continued.

Geologic age.	Formation.	Description of strata.	Topographic features.	Thickness.	Economic value.
Tertiary.	Green River formation.	Composed of shale, sandstone, and beds of fossiliferous rock. The shaly beds predominate and are very compact and firmly bedded. They are generally exposed in escarpments and high bluffs in which the weathered beds have a very characteristic chalky-white aspect. The shales are, however, of various shades of gray, drab, and light brown and are in many places hard and thin bedded. In some districts the lower part contains much massive white sandstone.	Characterized by plateaus where it is flat lying; these regions being bordered by high and abrupt escarpments at the margins or near the up-tilted areas. This formation is only slightly affected by weathering except where broken or exposed in a tilted position. It is cut by deep canyons along the stream channels, as it readily gives way to erosion by the attrition of mechanically transported harder material. It is well represented in the Roan or Book Cliffs Plateau, the Cathedral Bluffs, and the Gray Hills.	Measured sections exceed 2,400 feet; upper limit not reached.	Gilsonite and related hydrocarbons in the Uinta Basin.
	Wasatch formation.	Composed chiefly of clay or soft clay shale; commonly variegated, but various shades of red and drab predominate. It also contains beds of pebbles or conglomerate of very perfectly rounded silicious material, such as jasper, colored vein quartz, chert, or flint. Sandstones in places very massive and hard.	Commonly weathers to low valley or ridge country, at some places scarred by badland washes. It is usually distinguished by the banded or colored clays in the bluffs underlying or adjacent to the escarpments of the Green River formation. Cactus Valley, on Grand River, is eroded from these beds.	From 4,000 feet on the eastern side of the Uinta Basin to about 2,500 feet near the Utah line.	Oil and asphaltum deposits near Vernal, Utah.
	Name and correlation not determined; possibly of Fort Union or earlier age.	Beds not readily distinguished from the Wasatch in the Uinta Basin, but apparently more clearly differentiated in the Yampa field. As developed in the latter region they consist of massive white or light-colored sandstones and shales containing valuable coal beds sharply defined at the base by a conglomerate or conglomeratic sandstone, without doubt marking an unconformity of considerable magnitude.	Forms ridges and hilly country, especially where the sandstone members are prominent and numerous. Topography resembles that of the other coal-bearing formations, although not commonly so rugged as that of the Mesaverde.	Estimated as about 800 feet on Lay Creek north of Lay.	Workable coal.

Unconformity.

Rock formations of the northwestern Colorado coal fields—Continued.

Geologic age.	Formation.	Description of strata.	Topographic features.	Thickness.	Economic value.
Cretaceous.	Laramie formation.	Consists of massive sandstones and light-colored sandy or clay shales and many beds of lignite or subbituminous coal. As mapped, this formation includes the strata in which the massive sandstones are most prominent as distinguished from the softer strata of the underlying Lewis shale. As a whole the formation represents the transitional deposits of brackish or fresh-water origin, conformably overlying the uppermost marine formation. The lowermost sandstones mapped with the Laramie contain a marine fauna similar to that of the underlying Lewis shale.	In the eastern part of the Yampa River valley the Laramie is clearly distinguished from the underlying Lewis both lithologically and in its effect on the topography. It is similar to the overlying and supposedly lower Tertiary beds, from which it is distinguished only by the presence of the intervening conglomerate and evidence of unconformity. In the western part of the region the lower limit of the Laramie is less clearly defined, as the sandstones probably occur lower than they do farther east. The base of the formation is well represented at Hayden, in the escarpment bluff north of Yampa River.	Estimated as 1,200 feet between Craig and Lay.	Workable coal.
	Lewis shale.	Composed largely of soft dark-gray or black clay shale with calcareous seams and sandy beds, the latter developing in many places as massive and continuous ledges. The absence of the sandstones is the most prominent distinction between the Lewis and the overlying and underlying formations.	The outcrop of the Lewis shale is commonly marked by low valleys bounded on one side by the sandstone ridges of the Mesaverde and on the other by the escarpments of the Laramie. In the western part of the Yampa field the distinction is not so well marked, as sandstone occurs within the interval assumed to represent the Lewis.	Roughly estimated 1,000 feet in the valley of Horse Gulch.	Develops some valuable agricultural land on alluvial material along the valley bottoms.
	Mesaverde formation.	Includes an alternating succession of sandstone, sandy shale, and coal beds. The most prominent members are the massive white or light-colored sandstones. The weaker shaly members are more commonly covered by debris of the harder beds. The coal beds are even more generally concealed, although their positions are rendered conspicuous by the great amount of burning that has taken place along the outcrop.	Form hogback ridges and rugged, hilly country. The topographic forms are usually strong, contrasting with the valleys of overlying and underlying formations. The character of the ridges is chiefly dependent on the attitude of the underlying strata. Where steeply tilted the harder beds form sharp-crested hogbacks, and where more nearly horizontal they form broader flat or round-topped ridges bordered by escarpments or long, gentle dip slopes.	From about 3,000 to over 5,000 feet.	Coal. This formation commonly includes many thick beds of good bituminous coal.

Rock formations of the northwestern Colorado coal fields—Continued.

Geologic age.	Formation.	Description of strata.	Topographic features.	Thickness.	Economic value.
Cretaceous.	Mancos shale (including Benton fossils in its lower part).	A thick mass of dark drab or gray shale, containing lenticular members of sandstone or sandy strata, and near its base very constantly one or more beds of fine-grained dark sandstone and some limestone. In Utah the lower sandstone is lighter colored, coarse, and more prominent. In that part of the field coal is also found associated with these lower sandstone members. At the base is a compact dark slaty shale.	Forms open valleys and broad parks, many of which are extensive. These are commonly traversed by some of the larger streams, and in places broad bottom lands are developed. The sides of the valleys generally show terraces or "mesas" at various elevations above the valley bottoms. All these features are well represented in Agency Park, Axial Basin, Raven Park, and elsewhere.	5,000 feet.	Oil in the Rangely district. Agricultural lands where favorably situated. Workable coal near the base in the Vernal district.
	Dakota sandstone.	Commonly consists of two or more members of massive sandstone or quartzite, in many places conglomeratic, with sandy or clay shale intervening. In places carbonaceous shale is found in this formation. It is limited at the base by varicolored clays, clay shales, and associated strata now supposed to belong to the Jurassic.	Is developed as an independent hogback where tilted, and differentiated by intermediate shale bodies from the underlying Jurassic sandstones. Very commonly combined with the latter in high, sharp hogbacks with elevated broad dip slopes usually covered with brush or timber.	From 100 to 300 feet or possibly more.	

Below the formations described in the foregoing table a great thickness of older rock strata occur which are not described here, as they are not directly connected with the discussion of the commercially important coal fields.

AGE OF THE COAL-BEARING ROCKS.

As indicated in the table, workable coal is found in a number of formations, including the Mancos, Mesaverde, Laramie, and an overlying formation supposed to represent the Fort Union or earlier rocks. Beds of coal and carbonaceous or lignitic material are even more widely distributed in the geologic section. Two localities were observed where coal occurs in beds older than the Cretaceous formations described in the table. Of these one of possible commercial value in the Henrys Fork field, in Utah, is described on page 311. A thin bed of coal of doubtful quality has also been noted in Jurassic strata on upper Red Wash, on the south side of Blue Mountain, Routt County, Colo.

Carbonaceous shale somewhat resembling coal has also been noted in the sandstone in the lower part of the Mancos in the same general locality as that of the Jurassic coal just noted. Coal has been opened in a mine 3 or 4 miles south of Lily Park, Colo., where it occurs in beds closely adjacent to the Dakota sandstone.

The strata overlying the Dakota include by far the greater part of the valuable coal. A brief summary of the occurrences of the coals of the various formations is given below; this will be followed by more detailed descriptions of the individual coal beds.

The coal near the base of the Mancos shale is important in the Vernal field of Utah, where it is mined to a considerable extent for domestic use.

The Mesaverde is the most important coal-bearing formation in the region, constituting by far the largest extent of coal territory and containing the greatest thickness of workable beds.

The Laramie coal is found in the Yampa field north of Yampa River and is developed to a very moderate extent near Hayden and Craig.

The post-Laramie coal of Fort Union or earlier age is also found in the Yampa field and is developed in a small way at several points north of Yampa River.

GENERAL FEATURES OF THE MESAVERDE FORMATION.

As stated above, the Mesaverde is the most important of the coal-bearing formations in these fields. On account of the magnitude of this formation, which is approximately a mile thick in many parts of the Danforth Hills and Grand Hogback fields, the arrangement and character of its beds and the grouping of the coals are important factors in influencing the areal distribution of the coal available for development.

The Mesaverde formation is composed predominantly of sandstone and sandy shale. Among these strata the coal beds are usually arranged so that they may be naturally divided into three groups. Recognition of these groups of coal beds has already become fairly established in the local usage, especially in some of the better-known districts, where the whole Mesaverde section is exposed.

In the Uinta Basin the term "lower coal group" is applied to coal beds near the base of the Mesaverde formation. In the fields here discussed this group usually consists of a few unimportant beds of coal, locally of fair or good quality, but usually too thin to work. Where thicker beds occur they are commonly broken into many thin benches by bony or shaly material, so that the coals are in general not workable. Some exceptions to this rule occur, but they are not known in the area here described. The strata associated with the lower

coals are largely of marine origin, as shown by the fossils they contain. This lower marine portion of the Mesaverde formation is distinguished by a separate pattern on the geologic maps.

The middle group comprises most of the workable coal beds found in the Mesaverde formation. The strata associated with these coals are in many places rather sharply delimited from the lower marine part of the Mesaverde formation, both by the marked change in the character of the strata from barren below to coal bearing above, and in many parts of the fields by the occurrence of a large and conspicuous white sandstone bed just below the base of the coals. This may very properly be included with the lower or relatively barren part of the formation, as in numerous places it contains marine fossils. Where it can be identified it furnishes a very convenient key rock from which to measure the stratigraphic positions of the various beds that overlie it. As noted in previous reports on this general region, it is commonly referred to as the "white rock."

Above the "white rock," coal beds of the middle coal group show almost everywhere, either in weathered outcrops or more generally as bands of reddened and baked rock or slag, where the coal has been burned along its outcrop. Higher in the formation the coal beds are scattered irregularly and vary from place to place, so that individual sections do not correspond closely in the number and grouping of the coal beds. The massive sandstone ledges are by far the most conspicuous features, in many places masking by their débris the outcrop of the intervening strata of weaker rocks.

An upper coal group near the top of the Mesaverde section is commonly separated from the middle group by a considerable interval of relatively barren strata. There is some evidence that the coal of this part of the section is of lighter weight than the average of the older coals and that it usually slacks more rapidly, in this way resembling the subbituminous coals of the Laramie and later formations. Though this difference may not hold constantly throughout the fields, it seems nevertheless to be general.

The total thickness of workable coal in the whole formation of course varies largely. It is perhaps at or near a maximum at Newcastle, Colo., where 108 feet of coal is found distributed in seven workable beds. At Meeker the section is known to contain at least 75 feet of coal distributed in ten beds, with possibly others not shown by present development. Unfortunately the sections of this formation in the fields here described are too incompletely known to give any reliable estimates of the total amount of coal they contain.

The three coal groups defined in the report on the Yampa coal field do not correspond to the limits assigned to these groups in the western part of the same field or in the fields to the south. The lower and middle groups of the eastern Yampa field are not distinguished as

separate in the fields to the south and west and together are included in the middle group. The upper coal group is probably at approximately the same stratigraphic position in the two fields, although no positive evidence can be offered to prove this point.

STRUCTURE.

General outline.—The sedimentary strata were without doubt originally deposited in an approximately horizontal position, but they have later been tilted, exposing them in various attitudes and resulting in much irregularity in the outline of their outcrops. This displacement of the strata and subsequent erosion have also brought about the separation of some fields that were probably once continuous. It also seems likely that some of the deposits were laid down in separated basins and so may never have been continuous, although apparently separated by relatively narrow barriers.

Major structural basins.—The coal fields of northwestern Colorado lie in two major structural basins, surrounded by areas of older rock formations that are relatively uplifted. The northern of these two is known as the Green River Basin, which extends into Colorado as far as the upper valley of Yampa River. The Yampa coal field occupies a part of this basin. The southern of the two major structural basins is known as the Uinta Basin, and the Colorado portion is also termed the Grand River Basin. This is separated from the Green River Basin in the Yampa coal field by the anticlinal axis of the Uinta Mountains, which extends eastward from that range in Utah through Axial Basin and joins with the uplifts of the White River Plateau and the western spurs of the Rocky Mountain system. The Grand Hogback, Danforth Hills, and lower White River coal fields are a part of the Uinta or Grand River Basin of Colorado.

That part of the Uinta Basin which was examined during the last year extends from the Danforth Hills westward to and beyond the Colorado-Utah State line. The Green River Basin includes the western part of the Yampa field and the Henrys Fork field of Utah and Wyoming, which are also described in this report.

Minor folds.—Details of the minor structural features of these two major basins are brought out by the structure symbols on the accompanying maps. It is evident from the sinuosity of outcrop of the tilted strata that their positions at the surface are the direct result of the depth to which erosion has progressed into the structurally irregular underlying beds.

Larger folds of the White River and Vernal fields.—The structural irregularity of the northeastern margin of the Grand River Basin is pronounced, forming a series of domes and anticlines and correlative synclinal folds. As several of these features are referred to in the following pages in relation to their influence on the trend of the coal-bearing rocks, they will be briefly reviewed here.

South of the Axial Basin anticline and west of the Danforth Hills lies the Coyote Basin, or Crooked Wash, essentially a broad syncline toward which the coal-bearing strata dip from the east, north, and west and around which the rocks outcrop in a continuous rim except on the south side. A subordinate anticline with a north-south axis arches the strata through the very center of this basin, crossing White River at the mouth of Blacks Gulch, near Piceance Creek, but does not bring the coal rocks to the surface. West of the Coyote Basin syncline the structures are more intimately related to the folds of the Uinta Mountains, as these features are more or less symmetrical from Blue Mountain southward in Colorado and also from that uplift northward in the Utah part of the region. The summit and southern flanks of Blue Mountain are due to a great anticlinal flexure whose axis extends east and west and pitches in either direction. At its eastern extremity it bends toward the southeast and merges with the western flank of the Coyote Basin syncline. To the west this fold pitches more abruptly and disappears very abruptly near the Colorado-Utah State line. It has been called the Midland uplift or anticline, a name given to it in the early work of the Hayden Survey. Northwest of the termination of the Midland anticline a similar fold with axis parallel to that uplift and also pitching to the west, is recognized in Section Ridge. This fold extends westward as far as Green River and is referred to as the Section Ridge anticline. North of Section Ridge a still more pronounced arch of the strata, very similar in character and direction to the others, forms the high ridge known as Split Mountain, through which Green River passes in a canyon. This fold, known as the Split Mountain anticline, pitches to the west and disappears along the lower course of Brush Creek west of Vernal. North of Split Mountain a broad structural depression to which the name Island Park syncline is given lies between the Split Mountain anticline on the south and the main Uinta Range on the north.

South of Blue Mountain in Colorado a low, oval dome on White River is known as the Raven Park anticline, and this has already been described in some detail as an oil field.^a South of the Raven Park uplift a similar though broader and more gentle flexure occupies an extensive area on Douglas Creek. It has been convenient to give names to some of the intervening synclines, and such names are explained in the text.

Influence on distribution of coals.—All these folds influence the trend of the outcrops of coal-bearing rocks, and consequently a general knowledge of the distribution and arrangement of the folds is essential to an understanding of the relations of the various parts of the coal fields.

^a Gale, H. S., *Geology of the Rangely oil district, Rio Blanco County, Colo.*: Bull. U. S. Geol. Survey No. 350, 1908.

DETAILED DESCRIPTION OF THE COAL FIELDS.

SCOPE OF TEXT AND MAPS IN PRESENT REPORT.

The extent and areal distribution of the outcrops of the geologic formations, with special reference to those containing the valuable coals, are represented on the geologic maps (Pls. XVI-XX). These maps are arranged to suit convenience of publication and description, retaining the scale of 4 miles to the inch which was used in the reports on adjacent districts and which is also that of the Hayden and King maps of this part of Colorado.

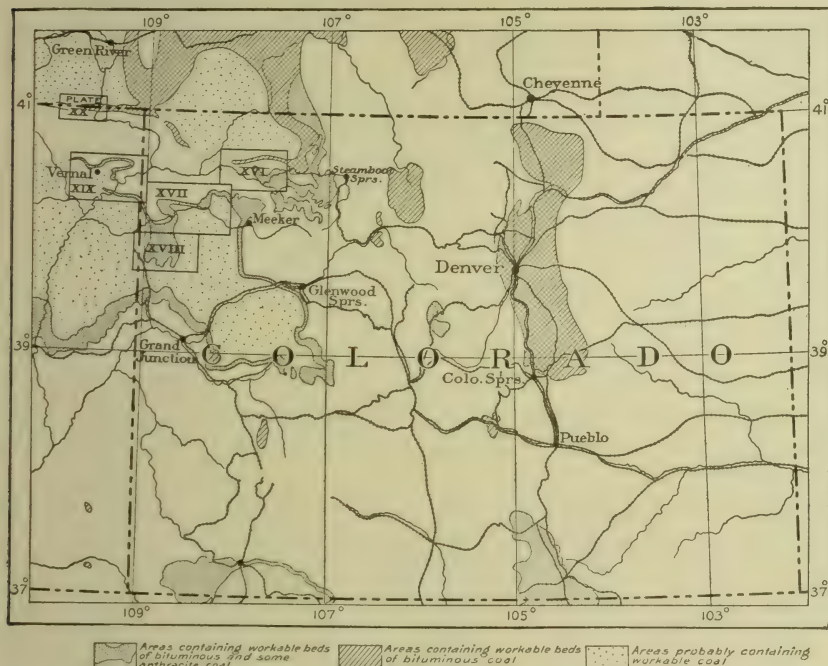


FIG. 5.—Map of Colorado and northeastern Utah coal fields, showing areas represented by Pls. XVI-XX: Western part of Yampa field (Pl. XVI); lower White River field north of the base line (Pl. XVII); Douglas Creek district, lower White River field south of the base line (Pl. XVIII); Vernal field (Pl. XIX); Henrys Fork field (Pl. XX).

In the brief space of this preliminary report only a very general description of the conditions in the several fields can be given in the text. The territory examined naturally belongs to several more or less distinct fields, as shown by fig. 5. These fields are described in the following pages.

WESTERN PART OF THE YAMPA FIELD.

DISTRICT COVERED IN PRESENT REPORT.

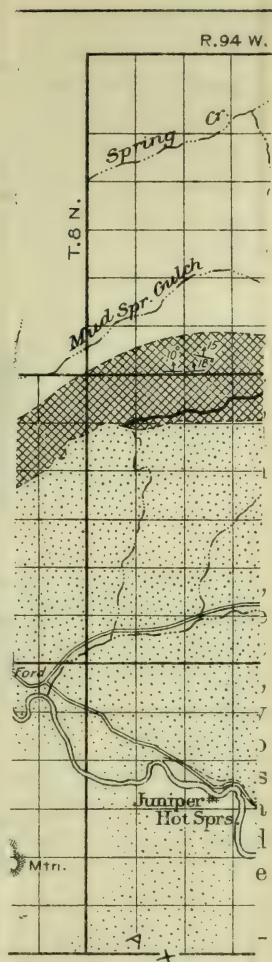
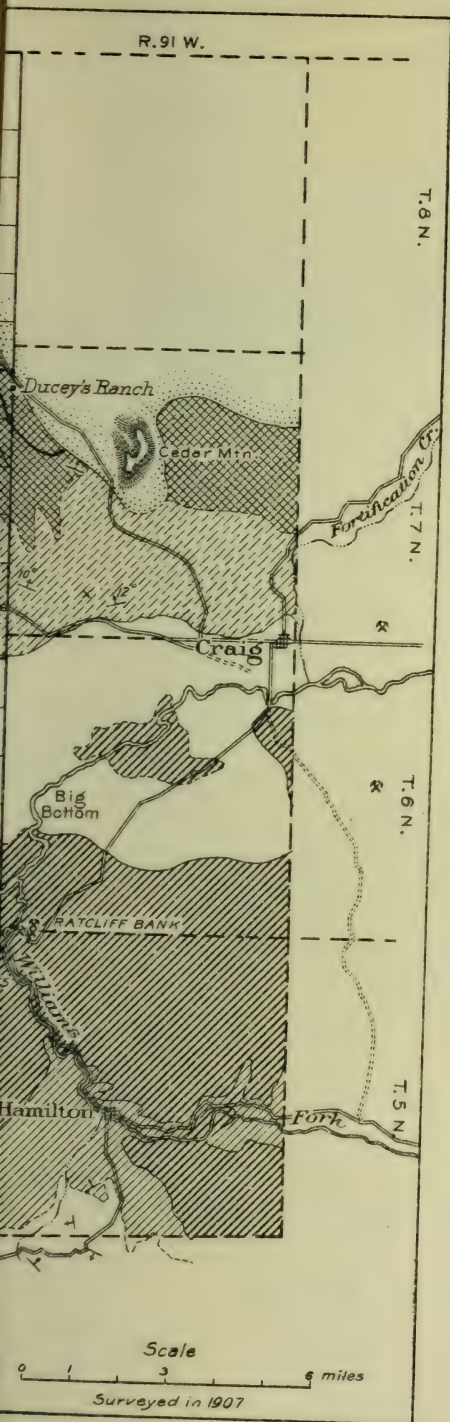
The examination of the Yampa field in the former work in that region was not carried on in much detail west of the mouth of Williams Fork, although the coal-bearing rocks of the Mesaverde and overlying

formations outcrop continuously westward from the main part of the Yampa field at least as far as Lay. In view of the recent completion of the township resurveys west of the line between Rs. 91 and 92 W., that part of the field was examined in more detail during the last season, and the map forming Pl. XVI embraces the results obtained during this examination.

MESAVERDE COAL.

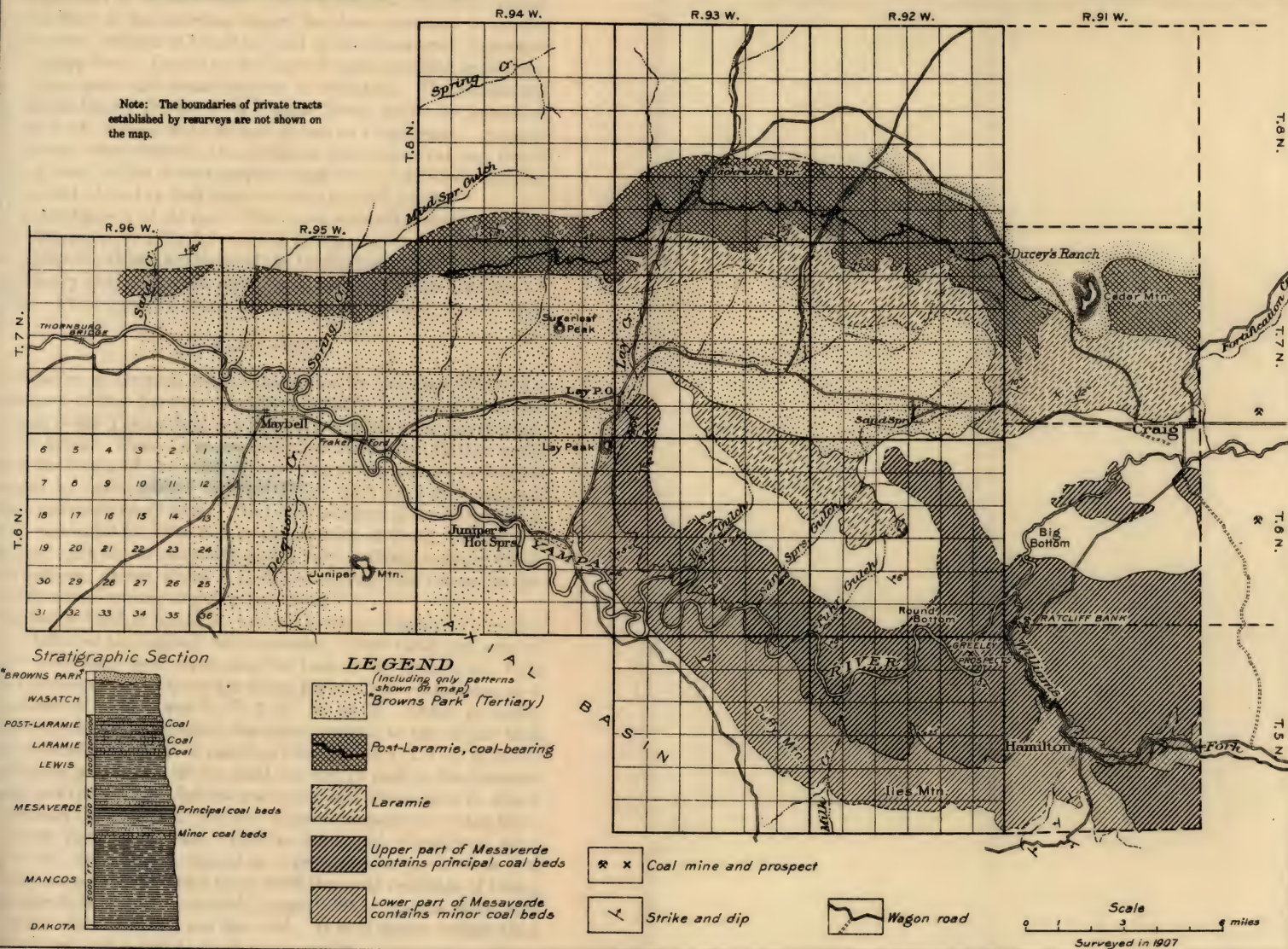
Distribution and structure of Mesaverde rocks.—Along the valley of Yampa River west of the mouth of Williams Fork the Mesaverde rocks are tilted in several broad folds. The principal structure in this part of the field is the Axial Basin anticline, which forms the southern limit of the Green River Basin. The strata rise toward the axis of that uplift, from the summit of which the Mesaverde formation has been eroded so that the coal field terminates with the southward-facing escarpments of Iles and Duffy mountains. Northeast of the Axial Basin uplift a corresponding syncline passes through Round Bottom, on Yampa River, with an axis approximately parallel to the major anticlinal fold. Northeast of the Round Bottom syncline a secondary anticline, with axis parallel to the other two folds, extends northwestward from the mouth of Williams Fork. This is exposed as far as Sand Springs, near the Craig-Lay wagon road, and doubtless influences the underlying structure much beyond that point, although concealed by the overlying unconformable deposits. The prevailing dips in all these structures are light, for the most part not exceeding 10° to 15° .

Typical sections and coal groups.—The complete section of the Mesaverde formation exposed in the western part of the Yampa field is about 3,500 feet thick. This resembles the section of the same formation exposed in the Danforth Hills, although in the Yampa field it appears to be somewhat thinner. The evidence on which the lower members of the formation in the two fields are correlated consists of (1) the structural relations in Axial Basin, (2) the striking correspondence in arrangement in the basal group of sandstones and shales on either side of the erosional break, and (3) the correspondence of fauna and flora obtained from the two sections, of which some representative collections have been made and studied by T. W. Stanton. The arrangement and grouping of the coal beds in the Yampa field correspond well with the sections exposed in the Danforth Hills. Above the lower and relatively barren zone no distinction can be made between the lower and middle coal groups as these were described in the report on the Yampa field, and they thus merge into a single large coal group. The lower coal group of this part of the field, as in the Danforth Hills, is recognized as a group of relatively inconspicuous beds occurring lower than any distinguished in the groups that were described in the report on the main Yampa field.



- LEGEND**
 (Including only patterns shown on map)
- "Browns Park" (Tertiary)
 - Post-Laramie, coal-bearing
 - Laramie
 - Upper part of Mesaverde contains principal coal
 - Lower part of Mesaverde contains minor coal

Note: The boundaries of private tracts established by resurveys are not shown on the map.



MAP OF THE WESTERN PART OF THE YAMPA COAL FIELD, ROUTT COUNTY, COLORADO
By Hoyt S. Gale, J. A. Davis, and C. W. Stoops

Total thickness of workable coal.—Little additional evidence beyond that contained in the previous report has been obtained as to the probable total amount of available coal in the Mesaverde formation in the Yampa field. Owing to the lack of more complete exposures, these figures must still remain largely as estimates. The section exposed at the Greely prospects on Yampa River, below the mouth of Williams Fork, reveals 30 to 50 feet of coal as a minimum. According to former measurements, the section so well exposed at Lay shows 55 feet of coal, within a stratigraphic range of only 320 feet, and the total amount of coal at that place is doubtless still greater.

Local development of the coal.—The most extensive development is at Lay, where the beds have been well prospected by A. G. Wallihan. Other prospects visited are those of the Greely group, just mentioned, a single entry in Horse Gulch, and several small prospects near Round Bottom. From none of these has any great amount of coal been mined.

LARAMIE COAL.

Distribution of Laramie strata.—As shown by the map (Pl. XVI), the outcrop of the Laramie formation extends westward from the main part of the Yampa field in a belt several miles wide, passing just north of Craig. These beds are doubtless continuous farther west, beyond the limits of the territory here described, but are so largely concealed by overlapping "Browns Park" beds that their outcrop covers a relatively small area. The total thickness of the formation is roughly estimated at 1,200 feet in the vicinity of Craig. There is a prevailing light dip to the north and a very uniform westerly trend of the outcrop, except where it is deflected from this course by the Round Bottom syncline and adjacent folds.

Coal beds.—Coal is found at various horizons, apparently irregularly distributed throughout the formation. Near Craig and also at Hayden some large beds occur near the base of the formation. Coal beds of considerable thickness are found higher in this formation, and are exposed in secs. 6 and 7, T. 7 N., R. 92 W. Other probably smaller beds at approximately the same horizon as the upper beds just mentioned were observed near Lay Creek, in sec. 7, T. 7 N., R. 93 W. No estimate is available of the total amount of coal in the Laramie section, as exposures are far too scattering and incomplete to afford the necessary data. About the best observed exposure is at the Kimberly bank, just east of Craig. Here an 8-foot bed of solid coal, with a dip of 14° N., has been opened in a prospect entry. It does not, however, seem to have found favor with the local residents of Craig, who prefer to make a considerably longer haul to get the Mesaverde coal rather than mine and use this coal. It is of lighter weight than the older coal and is said to slack more rapidly.

POST-LARAMIE COAL.

Nomenclature and stratigraphic position.—A considerable group of workable coals is found in the formation unconformably overlying the Laramie. On account of the uncertainty as to whether these beds should be called Fort Union and classed as a part of the Tertiary system or form an upper and unconformable part of the Cretaceous system, the coals are for the present referred to as post-Laramie, as they constitute the only recognized coal group overlying the Laramie formation in this field. The zone containing the workable coals is in the lower part of these later beds. The principal coal group appears to be in a zone 400 to 500 feet above the basal conglomerate member already described as marking the unconformity at the top of the Laramie.

Distribution of post-Laramie coal-bearing strata.—The coal-bearing beds immediately succeeding and overlying the Laramie in the Yampa field outcrop in a belt of hills and ridges north of the Laramie district. They extend continuously westward from the vicinity of Cedar Mountain as far as and probably beyond Maybell, but beyond Sand Creek they are concealed by the unconformable "Browns Park" beds.

Local development of the coal.—West of Cedar Mountain these coals are found near Ducey's ranch, in the northeast corner of T. 7 N., R. 92 W., where a local bank has been opened on one of the beds in the NW. $\frac{1}{4}$ sec. 2. The coal exposed at the entry is 7 feet 2 inches thick and is overlain by soft clay or shale; about $2\frac{1}{2}$ feet of the top of the coal has been left as roof. West of this point the coal may be readily traced by numerous outcrops through T. 8 N., Rs. 92 and 93 W., and T. 7 N., Rs. 94 and 95 W.

In the valley of Lay Creek one of the beds of this group has been worked for local use at the Blevins mine, in the NW. $\frac{1}{4}$ sec. 28, T. 8 N., R. 93 W. The coal at the Blevins mine appears to be fairly representative of most of the coals of this group. The bed is 11 feet 4 inches thick, and all of it is taken out in the entry, together with about 5 inches of laminated blue clay at the top. Above the clay is a massive, coarse-grained white sandstone forming a solid roof at least 40 feet thick. The beds dip 4° N. 5° E. The coal bed is without seam or parting. The floor is covered by 4 or 5 inches of bony coal, below which is a solid white sandstone. There are no signs of burning of the outcrops in this immediate vicinity; in fact, the coals of this group seem less subject to combustion at the outcrops than the older coals.

Some of the post-Laramie coals are also opened in Spring Creek Gulch, in T. 7 N., R. 95 W., where several local banks have been worked at various times.

Character of the post-Laramie coal.—The coal breaks down at the face of the Blevins mine very easily when loosened, but is very tough

and has to be shot, as it can not be picked out before it is broken. It is reported that exposure to the open air for three weeks will slack the coal completely. When first lighted it emits a pale blue smoke resembling that given off by dry soft wood, but this color soon disappears, leaving a clear, smokeless flame.

The analysis of the post-Laramie coal (No. 5514, p. 314) shows it to be of somewhat lower efficiency than the average Mesaverde coals of the Yampa field. The coal would probably fall in the class of subbituminous coals formerly described as black lignite. The amount of moisture ($12\frac{1}{2}$ per cent on air-dried coal) is rather too high to place the coal in the bituminous class, although the fixed carbon (50 per cent) compares very favorably with that in many of the high-grade coals. The ash ($7\frac{1}{2}$ per cent) is a fair average for commercial coal. The appearance of this coal when first mined is very like that of the high-grade bituminous coals. Its principal disadvantageous feature is the fact that it slacks readily when exposed to the air.

Total thickness of workable beds.—All the coal beds of this group are not exposed in any one section, and hence complete measurements were not obtained in the present investigation. A. G. Wallihan, of Lay, states that some good exposures are to be found in the ridges west of Emerson's ranch, on Lay Creek, where he claims to have opened by digging twelve different coal beds, ranging from 4 to 20 feet in thickness and aggregating a total of more than 100 feet of workable coal as measured at the croppings.

LOWER WHITE RIVER FIELD.

POSITION AND OUTLINE.

West of the Danforth Hills the Mesaverde strata and the valuable coal beds which they contain are continuous to and beyond the Utah line, as shown by Pl. XVII. This field occupies in part the divide between White and Yampa rivers, but by far the greater part of it lies in the drainage basin of White River in Colorado. As White River joins Green River about 40 miles west of the Colorado-Utah line, and as the coals are mostly confined to the Colorado portion of that drainage basin, it has seemed most appropriate to apply the name "lower White River" to the Colorado field.

This field includes a continuous outcrop of the Mesaverde rocks, extending from the northwestern part of the Danforth Hills, describing roughly a semicircle around the north end of Crooked Wash, or Coyote Basin, and thence passing southward along Piñon Ridge to White River at the mouths of Wolf and Yellow creeks. From this point the outcrops of the coal-bearing rocks bend abruptly westward, forming a narrow hogback on the north side of White River. In the

vicinity of Raven Park the rocks spread out in broader folds and cover an extensive territory, reaching from the vicinity of Blue Mountain on the north to a line within a few miles of the Book Cliffs divide at the head of Douglas Creek on the south. Northwest of Raven Park the coal-bearing strata have been traced continuously into Utah as a narrowing belt, which is described in a subsequent section of this paper as the Vernal field.

The examination of the lower White River field was commenced in Tps. 4 and 5 N., R. 96 W., and continued westward along the outcrops of the coal-bearing rocks, as indicated on the map (Pl. XVII).

AGE OF COAL-BEARING ROCKS.

As explained briefly under the heading "Stratigraphy," the Mesaverde constitutes the only important coal-bearing formation of the lower White River field, the Laramie being absent from the geologic section south of Axial Basin. Furthermore, the post-Laramie formations appear to be barren of valuable coals, and it is still uncertain if any of the strata of the Grand River Basin, of which the White River field is a part, are strictly to be correlated with the coal-bearing strata that overlie the Laramie beds of the Yampa field. The correlation of the basal Tertiary beds of the two fields will therefore be left an open question for the present, as it is necessary to discuss here only the Mesaverde beds in the fields of the southern basin.

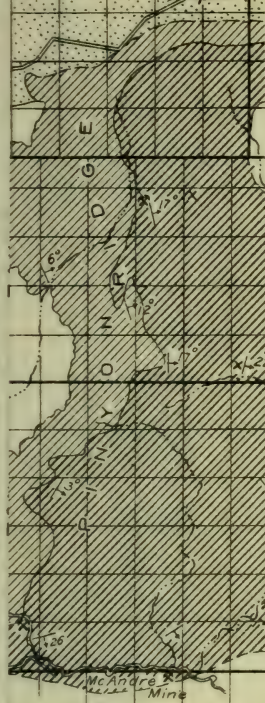
SUBDIVISION OF THE WHITE RIVER FIELD.

The lower White River field is considered in two parts as divided at the base line, and is represented in this way on Pls. XVII and XVIII. This is done partly as a matter of convenience for publication of the maps and partly to separate the results of the more detailed examination made north of the base line from those of the hasty reconnaissance of the area south of the line. Most of the territory north of the base line has been either recently resurveyed by the General Land Office, or the contracts have been let and it is expected that the work will be completed in the near future. On the other hand, in the territory south of the base line and west of the twelfth auxiliary guide meridian, the old land surveys are believed to be in large part practically without value, and very few corners were discovered in the present investigation. In the Douglas Creek drainage basin only three land corners were found, and these do not appear to check with each other nor to agree with their stated distances and directions from the base line. These corners are situated in the immediate valley of Douglas Creek, and it is extremely doubtful if many corners were ever set or if the lines were run at all in the adjoining hills. An attempt to classify the lands in this southern area, therefore, seems unwarranted at present.

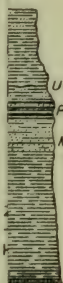
R.98 W.

Promontory
Plateau

Twelvemile
Sprs.



Section



Unconformity

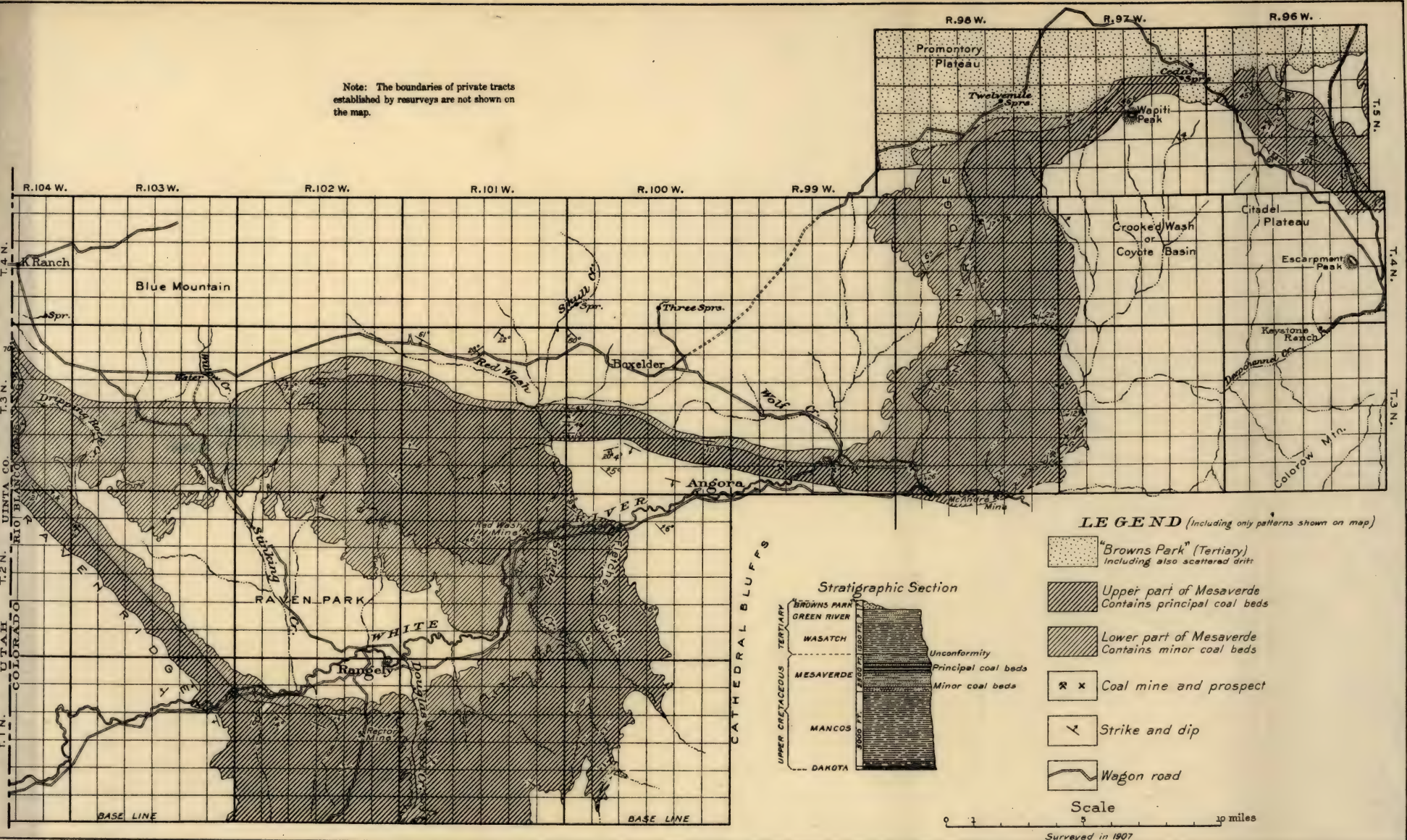
Principal coal beds

Minor coal beds



NE, COLORADO

Note: The boundaries of private tracts established by resurveys are not shown on the map.



AMERICAN & BRADSHAW CO., PHOTO-LITHOGRAPHERS, WASHINGTON, D. C.

MAP OF THE LOWER WHITE RIVER COAL FIELD, NORTH OF THE BASE LINE, COLORADO

By Hoyt S. Gale, J. A. Davis, and C. W. Stoops

AREA NORTH OF THE BASE LINE.

General section of Mesaverde formation.—As the rocks of the lower White River field form a direct westward continuation of the outcrops of the same formations that are exposed in and adjacent to the Danforth Hills, no sharp distinction nor marked variation in the beds of the two fields is to be noted. As explained more in detail in the discussion of the Vernal field, the Mesaverde appears to become thinner as traced toward the west, being in the vicinity of Red Wash only 2,500 feet thick, or half the thickness exposed on White River near Meeker. This thinning is thought to be due to the fact that erosion of a former land surface had progressed to a considerable depth into those beds before the succeeding Tertiary strata were laid down upon them.

Total amount of coal in the Mesaverde section.—As explained in the published report on the Danforth Hills coal field, the only available section where satisfactory measurements of the total amount of coal in the Mesaverde formation can now be had is that exposed on White River a few miles below Meeker. Here at least 73 feet in ten beds, each of workable thickness, was well enough opened by development so that the coal could be measured. It is thought likely that a complete measurement at that place would show even more coal than this. Unfortunately the scattered prospects and small amount of development in the lower White River field do not permit even a fair estimate of the total amount of coal. To judge from the few exposures available, and from such general indications as natural exposures of coal smut and the relative intensity of baking where coal beds have been burned in outcrops, the distribution of the groups of coal beds is thought to be very similar to that of the Danforth Hills. Owing to the thinning of the coal-bearing formation toward the west, thought to be caused by the absence of its upper members, it seems likely that the upper coal group of the Danforth Hills may be partly lacking west of Coyote Basin, and it is almost certainly absent a short distance west of the mouth of Wolf Creek.

An additional and probably still more important factor influencing the total amount of available coal in the lower White River field is an apparently local decrease in the thickness and number of workable beds in the part of the formation exposed between the district at the mouths of Wolf and Yellow creeks and a district just west and south of the mouth of Red Wash. Here, in spite of relatively more active local demand for fuel supply in the adjacent valley of White River, but few important coal beds seem to have been discovered, and several that are of workable thickness are badly broken by layers of shale or bone. With the possibility that valuable beds will still be discovered in this vicinity, it seems very likely, nevertheless, that the total

thickness of available coal here will prove to be but a fraction of that contained in the Mesaverde section near Meeker.

In the strata surrounding the Raven Park anticline the total amount of coal evidently increases again, as is shown by the prospects and a few local mines and by the abundance of large beds of slag and burned rock. An estimate based on the observed indications would, however, place the total thickness in the maximum sections as not more than one-half to two-thirds that of the Danforth Hills field, and probably much less in many parts of that area.

Local descriptions.—The general character of this coal field may be judged from a brief review of some of the observed outcrops and a general description of the field.

South of Juniper Mountain, in Axial Basin, near Cedar Springs, Twelvemile Springs, and Wapiti Peak, the Mesaverde rocks occupy the main divide between Yampa and White rivers. A small amount of prospecting recently done in this general region has served to show some thick beds of excellent bituminous coal. Some exposures near Wapiti Peak indicate beds 10 feet or more in thickness. Most of the dips in this district are steep, 20° to 60° , and are toward the south, or inward toward the center or axis of the Coyote Basin syncline.

Along Piñon Ridge, on the west side of Coyote Basin, the rocks are tilted at lighter angles. The coal beds constitute two groups, separated by a relatively barren zone, so that the area of coal land is also split into two strips or zones corresponding to these outcrops. A coal bank or prospect drift has been dug in or near the NW. $\frac{1}{4}$ sec. 15, T. 4 N., R. 98 W., where coal 5 feet 3 inches thick is developed under a good sandstone roof with an easterly dip of 17° . The upper zone is prospected in the eastern side of sec. 25, T. 3 N., R. 98 W., by a drift 30 feet in depth exposing 6 feet of coal with a dip of 3° SE. To judge from the number and size of the surface indications, many other and doubtless some thicker beds occur in this region.

Along the valley of White River below this place the local settlement has created a greater demand for coal, but, as stated above, observed exposures seem to indicate a notable decrease in the amount of available coal in the Mesaverde formation. A few mines have been opened near the river banks. The Bassett mine, in or near sec. 31, T. 3 N., R. 98 W., shows a bed 3 feet 7 inches thick, which appears to contain very good coal, probably similar to the average Mesaverde coal in the Meeker district. An old entry south of the river, near the mouth of Wolf Creek, exposes at least 8 feet of good coal, which appears to be only part of a thicker bed, although there is much bony material in the section. West of the mouth of Wolf Creek an old mine known as the Stadtman bank shows at about the same horizon a thinner bed consisting of two benches which together contain 4 feet 2 inches of good coal. At Angora post-office, on the north side of the

river, two beds at about the same horizon have been opened. In one of these 6 feet 4 inches of coal has been mined, leaving about 1 foot 3 inches of good coal in the roof. A bed stratigraphically about 80 feet lower shows 3 feet 7 inches of good coal that has also been worked.

All the Mesaverde rocks of the Angora district are steeply tilted, forming a long, narrow hogback, approximately parallel to the course of White River. West of Angora this ridge continues for several miles to the region where the influence of the Raven Park anticline broadens the outcrop of the coal-bearing rocks and considerably enlarges the available coal field.

The coal-bearing rocks encircle the Raven Park anticline, although the more important coal beds are completely eroded on the north side of it between the Raven Park and Blue Mountain folds. The coal rocks dip away in all directions from Raven Park as a center or axis, for a greater or less distance, according to the proximity of other folds that modify this simple structure.

DOUGLAS CREEK DISTRICT, SOUTH OF THE BASE LINE.

Location and extent.—The coal-bearing rocks of the White River field are continuous south of the base line in the vicinity of Raven Park, forming a considerable area of actual croppings of the principal coal-bearing group of the Mesaverde formation which lie mainly in the drainage basin of Douglas Creek and its tributaries. This district, as shown by Pls. XVII and XVIII, is a part of the lower White River field, and the division along the base line is arbitrary, as already explained.

General structure.—Structurally the Douglas Creek district is probably continuous with the Book Cliffs coal field, on the Grand River side of the Book Cliffs divide. Between these two fields the coal-bearing rocks are buried under several thousands of feet of overlying strata in the high hills of the Roan or Book Cliffs plateau.

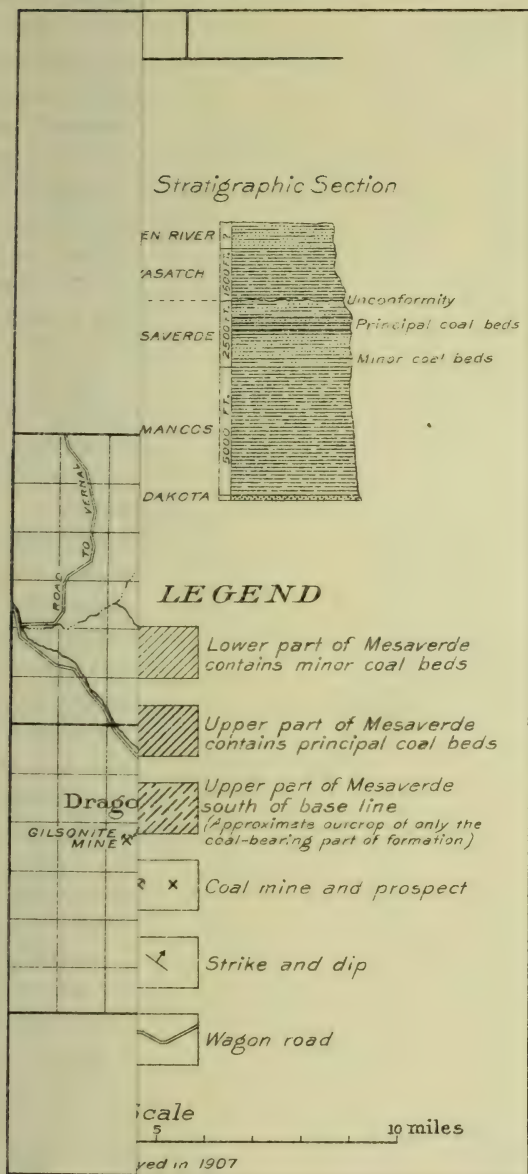
The structure of the district is perhaps most clearly revealed by a general view from the high escarpments surrounding the valleys and somewhat broken and hilly "parks." The bordering escarpments expose the bare ledges of the Tertiary strata dipping away in nearly all directions from the eroded center. In passing up the valley of Douglas Creek southward from White River the beds at first dip south, conforming to the structure of the Raven Park anticline. Before the base line is reached, however, they assume a practically horizontal position and then may be seen to rise toward the south, approximately at the grade of the streams. This structure is very regular, and with the exception of a few small faults, mentioned in a following paragraph, the strata continue to rise gradually southward to a point about 3 miles south of the N Bar ranch, which is situated in the main

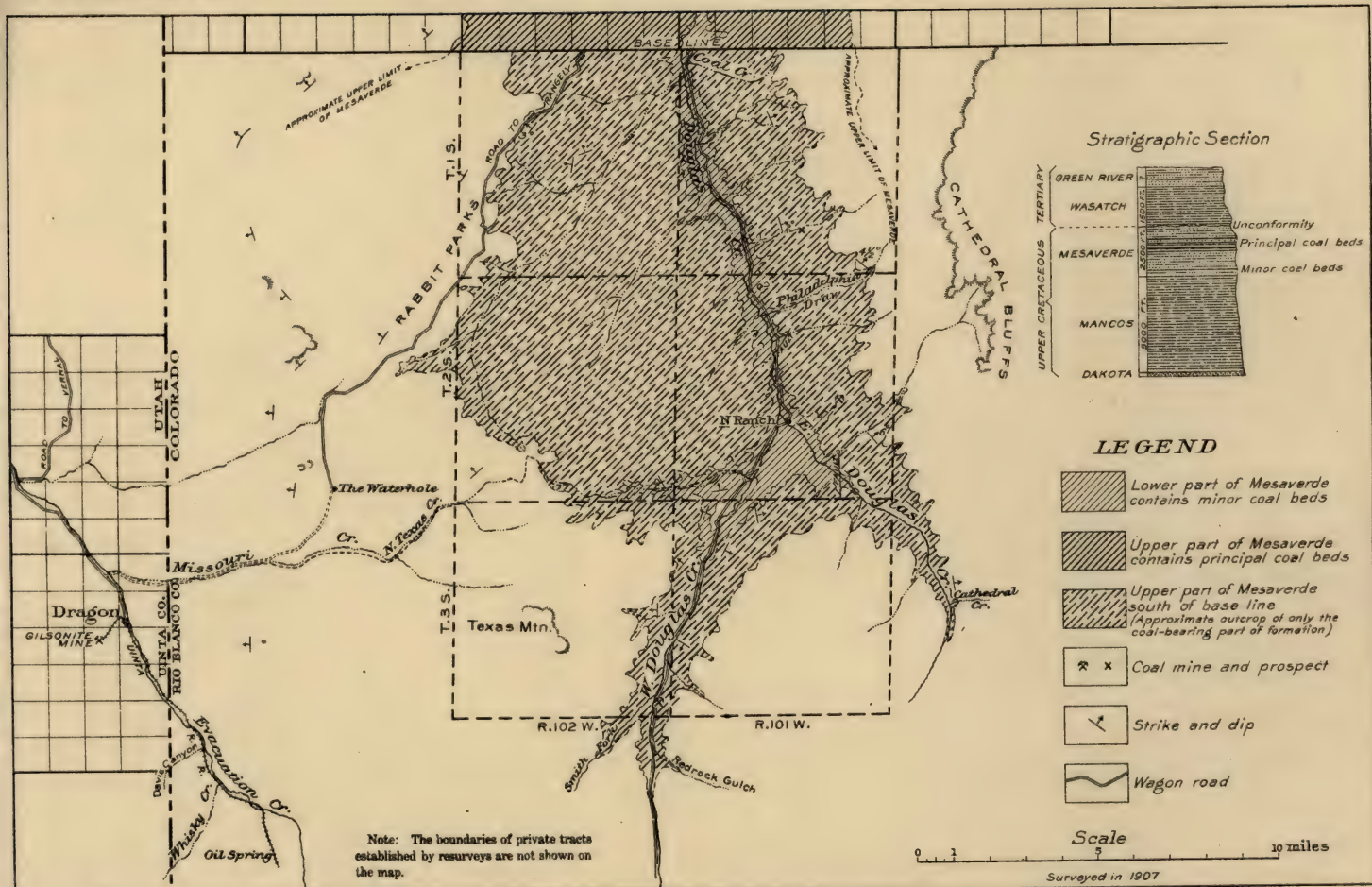
forks of the creek about 18 miles south of White River. (See Pl. XVIII.) South of the N Bar ranch, on the west fork of Douglas Creek, a small topographic basin opens out, evidently eroded from the shale at the base of the Mesaverde formation, and this is therefore the center of a structural dome or uplift, from which the beds may be observed to dip outward in all directions. At a point just above or south of this valley the strata bend abruptly down (southward) and there may also be a fault at this place. For some distance south of this point the beds are horizontal, but farther on they again rise approximately at water grade until they approach the headwaters of this branch of Douglas Creek. Here the coal-bearing rocks, although still rising toward the south, pass below the surface-water level. Thus this group of beds apparently extends under the Roan or Book Cliffs plateau only 10 to 15 miles north of the outcrops of the same formation on the south side of that divide, in the Grand River drainage basin.

In the western part of the Douglas Creek district the strata lie very nearly horizontal, with more or less irregularity of structure along the margin of the basin country, this being evident in the sinuosity of the limiting rim of the escarpments of the Green River formation. The general light dip toward the west or into the main Uinta Basin of Utah is, however, evident in the overlap and succession of higher and higher beds in that direction; so that the coals are probably buried at greater and greater depth by the accumulation of younger beds.

Faults.—A number of faults were observed in the Douglas Creek district, as well as numerous local slides or slumps. Two miles north of the N Bar ranch a fault trending N. 30° E. crosses Douglas Creek with a downthrow of 200 feet, more or less, on the south side. This fault brings the coal-bearing strata down to stream grade for a short distance, but beyond they rise again southward to the ridge tops—their customary situation. Another fault was observed on the east fork of Douglas Creek about 2 miles above the N Bar ranch. The direction of this fault is about N. 4° W., and the downthrow is 200 or 300 feet on the east side. The fault plane seems to be inclined toward the west at a steep angle on the north side of the gulch and toward the east on the south side of the gulch. The strata are sharply bent, showing the drag near the fault, and the burned coal-bearing strata are dropped to water level on the east side. The abrupt fold above the small anticlinal basin on the west fork of Douglas Creek is probably accompanied by one or more faults, and in this displacement the downthrow is on the south side.

Stratigraphy and occurrence of coal.—The stratigraphic section exposed at the main forks of the creek, near the N Bar ranch, is more or less typical of the Mesaverde rocks so extensively exposed along the canyon walls that line Douglas Creek. The lower 400 feet above





ANDREW S. GRAMER CO., PHOTO-LITHOGRAPHERS, WASHINGTON, D. C.

RECONNAISSANCE MAP OF THE DOUGLAS CREEK DISTRICT, LOWER WHITE RIVER COAL FIELD, SOUTH OF THE BASE LINE, COLORADO

By Hoyt S. Gale, J. A. Davis, and C. W. Stoops

water level is composed of huge white cliff-forming sandstone beds and some intervening shale, the whole somewhat conspicuous by contrast through the absence of any signs of burning. These beds are thought to represent in part at least the lower, relatively barren sandstone portion of the Mesaverde formation. At the base, near the creek level, is a coal bed about 8 inches thick, noticeably of lenticular character, and this is thought to be one of the lower coal group described on page 289. This bed shows much variation, thickening and thinning and dividing in a manner similar to that sketched in the published plate of Endlich's report.^a It is doubtless 300 to 400 feet or more above the base of the Mesaverde formation as exposed around the margin of Raven Park. The strata above the huge white sandstone bed show a section of about 300 feet reaching to the summits of the adjacent peaks and ridges, composed of shale and sandy beds, all fire reddened or colored by heat and baked as hard as pottery ware. This burned rock is exceedingly magnetic, probably owing to the reduction of the iron from the ferruginous seams contained in the strata before they were burned.

In a rather extensive territory adjacent to the lower valley of Douglas Creek, or including nearly all except the farthest headwaters of that stream, the middle or principal coal group of the Mesaverde can be readily traced by the eye from any prominent point overlooking the district or by traveling along the canyon bottoms. The brilliantly colored rocks may be seen to occupy in large part the summits of the ridges, whereas the canyons are commonly cut into the more massive white beds that everywhere underlie these coals.

On the west fork of the creek, above the small anticlinal basin previously mentioned, the principal coal group may be traced approximately at water level to a point within 5 miles of White's ranch in the upper valley of the main stream. The lower bluffs bordering the canyon form an almost continuous rim of brilliant vermilion rocks. The most brilliant of these is a zone 100 to 300 feet or more in thickness. At the forks of the west fork of Douglas Creek, about 8 miles above the N Bar ranch, an old entry exposes a bed of coal that has been worked for domestic use at an old settlement said to have been known as Smith's ranch. Now, however, both ranch and coal entry are abandoned and fallen into ruins.

The east fork of Douglas Creek runs approximately parallel to the high escarpment of the Green River formation known as the Horseshoe of Cathedral Bluffs. It also follows approximately the upper limit of the outcrop of the coal-bearing rocks, a geologic boundary which trends in the same direction as the high rim of the Green River bluffs. All these beds have light dips, and the formation above the principal coal-bearing group carries a great series of mass-

^aTenth Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1878, Pl. V, p. 81.

ive sandstone beds of cliff and ledge forming character, all of which appear to be almost identical with the unbaked sandstones of the coal-bearing rocks. Just between the sandstone ledges of the upper Mesaverde or lower Wasatch and the foot of the main-escarpment of the Green River shale there is on Cathedral Creek and elsewhere a deep, open valley, showing that there exists a zone of weaker or less resistant beds in the upper Wasatch or lower Green River formation. Some clays of red and white color occur, but are not so universally distinctive of the Wasatch as they are in many other parts of this general region.

The principal coal district immediately accessible is, as before stated, restricted to the Douglas Creek drainage basin. Baked rocks indicative of the burning of coal beds are a conspicuous feature in nearly all the bluffs that border the main stream as far south as a point beyond the principal forks. These burned rocks were described in a report of the Hayden Survey by F. M. Endlich,^a who thought they represented the reddish strata of the Wasatch formation, evidently failing to recognize the significance or cause of their color. The red cliffs, slag, ashes, baked and hardened rock, and clinker are so conspicuous that it seems as if they could scarcely be overlooked by anyone who travels through the region. There are also natural exposures of the coal itself, but these are comparatively rare. For some distance along the gulch or canyon walls the sandstone on the west side of Douglas Creek south of the base line outcrops in brown and weathered ledges with numerous reddened bands, having a slight resemblance to the beds found in the red and white banded Wasatch strata which normally overlie these Mesaverde rocks in the fields of the Uinta Basin.

Owing to the sparsity of settlement in this district, but little demand has been created for the development or use of any of the coals that might be available. A single local coal bank in a gulch about $1\frac{1}{4}$ miles northeast of the N Bar ranch has been worked within the last few years for domestic use at the ranch. It consists of a short slope running down N. 25° E. on a pitch of 5° . The dip of the beds is about 7° N. 10° W. The coal itself is 5 feet thick and possibly thicker, the floor being concealed in the present entry, so that a complete measurement could not readily be obtained. The roof consists of a thin-bedded sandy carbonaceous shale 2 feet 3 inches thick, overlain by a massive sandstone at least 15 feet thick. The coal is apparently of good quality, similar to the coals of the Meeker district, but it seems to have been somewhat affected by the heat from the huge burned zone that overlies it. This bed is one of the lowest of the middle coal group of the Mesaverde formation. The strata do not appear to be burned at all on the east side of the gulch

^aTenth Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1878, p. 80.

at this place, and the coal should be available there from the higher beds as well as from the one opened at the mine. Owing to its peculiar situation it is very doubtful if all of the coal of the Douglas Creek district can be assumed to be of commercial value at the present time. The almost universal burning in this part of the field has destroyed practically all of the coal at its outcrops, and by reason of the location of these beds in the summits of the ridges the burning may also have extended to considerable depth. The fact that much of the coal is situated wholly above ground water would make the complete burning of practically all the valuable beds very probable in many and perhaps most of the narrow ridges. Such a condition is all the more likely on account of the intricate network of steep canyons that intersect the region. The coal is thus subdivided into patches of an almost infinite detail of outline, the actual tracing of which would be rather difficult.

Toward the flanks of the broad, gently arched uplift these coal-bearing beds descend to and below water level or are more deeply covered, and in that portion of the district they are thus in more favorable positions and attitudes for mining purposes.

Throughout the western part of the district, or west of the actual drainage basin of Douglas Creek itself, no coal was noted, but it is evident that erosion has progressed rather deeply into the Wasatch beds at many points, and it is very likely that some of the more valuable coals may some time prove to be accessible at no great depths within these valleys, should demand ever be made for their development.

East of the settlement at Dragon, which is the terminus of the Uintah Railway, the upper valleys of Evacuation, Missouri, and Texas creeks are evidently eroded in the Wasatch beds underlying the Green River formation. These strata are shown by the bluffs of red and white banded clays and soft sandstones which line the lower canyon walls or form the bare washes in their lower valleys. These valleys are covered with slabs and blocks of oolitic rock and sandstone.

Character of the coal.—It seems fair to assume that the coal of this district is similar in character and thickness to that of the White River districts to the north and also to that of the better known and exploited fields on the south side of the Book Cliffs divide. Analyses of coals from the south side of Raven Park (Nos. 5519 and 5520, p. 314) are doubtless as truly representative of the Douglas Creek district as they are of the White River field in general.

A comparison of the relative efficiency or heating value of this coal, as shown by the calorimetric determinations, indicates that it is very similar to most of that in the Danforth Hills field and also to the Mesaverde coal of the Yampa field of Routt County, and that it may be properly classed as bituminous.

VERNAL FIELD.

LOCATION AND SETTLEMENT.

The valley of Ashley Creek, in which the town of Vernal, Utah, is situated, contains perhaps the most extensive settlement in this part of the State, or at least in the northern part of Uinta County. This district supports a prosperous agricultural community of considerable importance.

CHARACTER OF THE UTAH LAND SURVEYS.

West of the State line and east of the Green River valley no land-survey corners were found that could be identified with any certainty, and although some satisfactory surveys may at one time have been made in this territory it seems very likely that the corners if ever established were not permanently marked, and that only slight and rather uncertain evidence of them remains to-day. It also seems clear that the original surveys of Utah overlapped the Colorado State line. This was probably due to the uncertainty regarding the correct location of that boundary at the time of the work.

The map of the Vernal field presented here depends for its adjustment primarily on the control obtained from a railroad survey extending from Colorado down Cliff Creek to Green River, and also on plane-table traverse and triangulation done during the present investigation. The land lines east of Green River shown on the map are projected through from corners found in the valley lands. West of Green River the more extensive settlement and farming lands laid out by subdivisions and largely fenced afforded more complete evidence of the land-survey system.

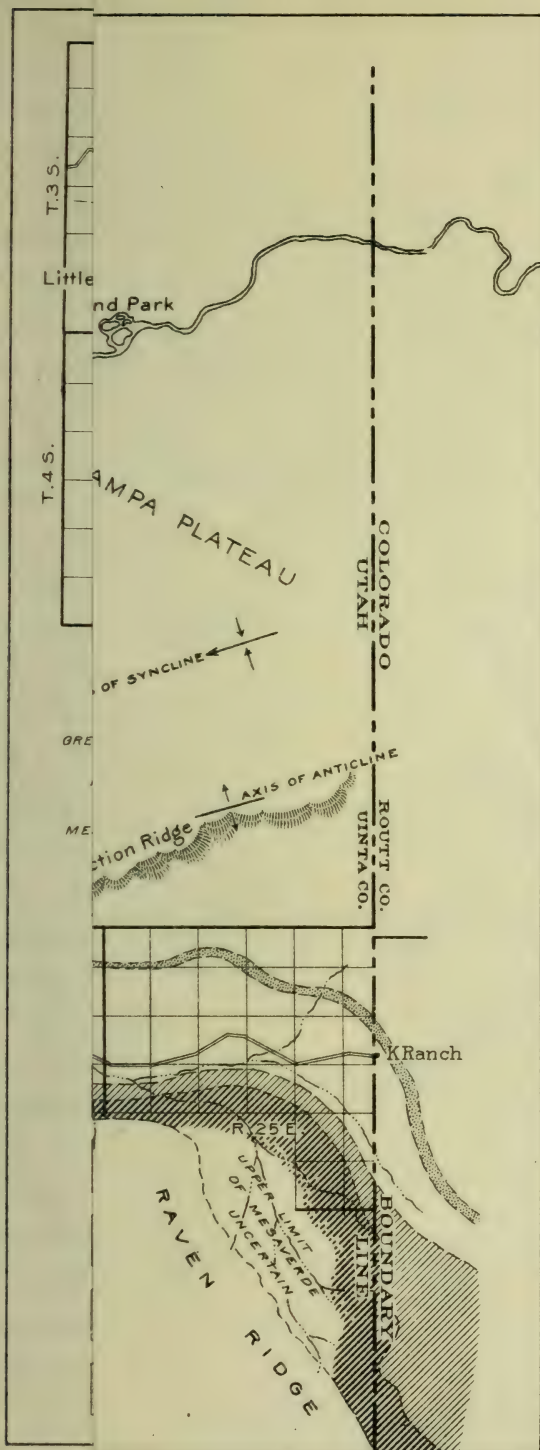
RELATIONS TO THE COLORADO FIELDS.

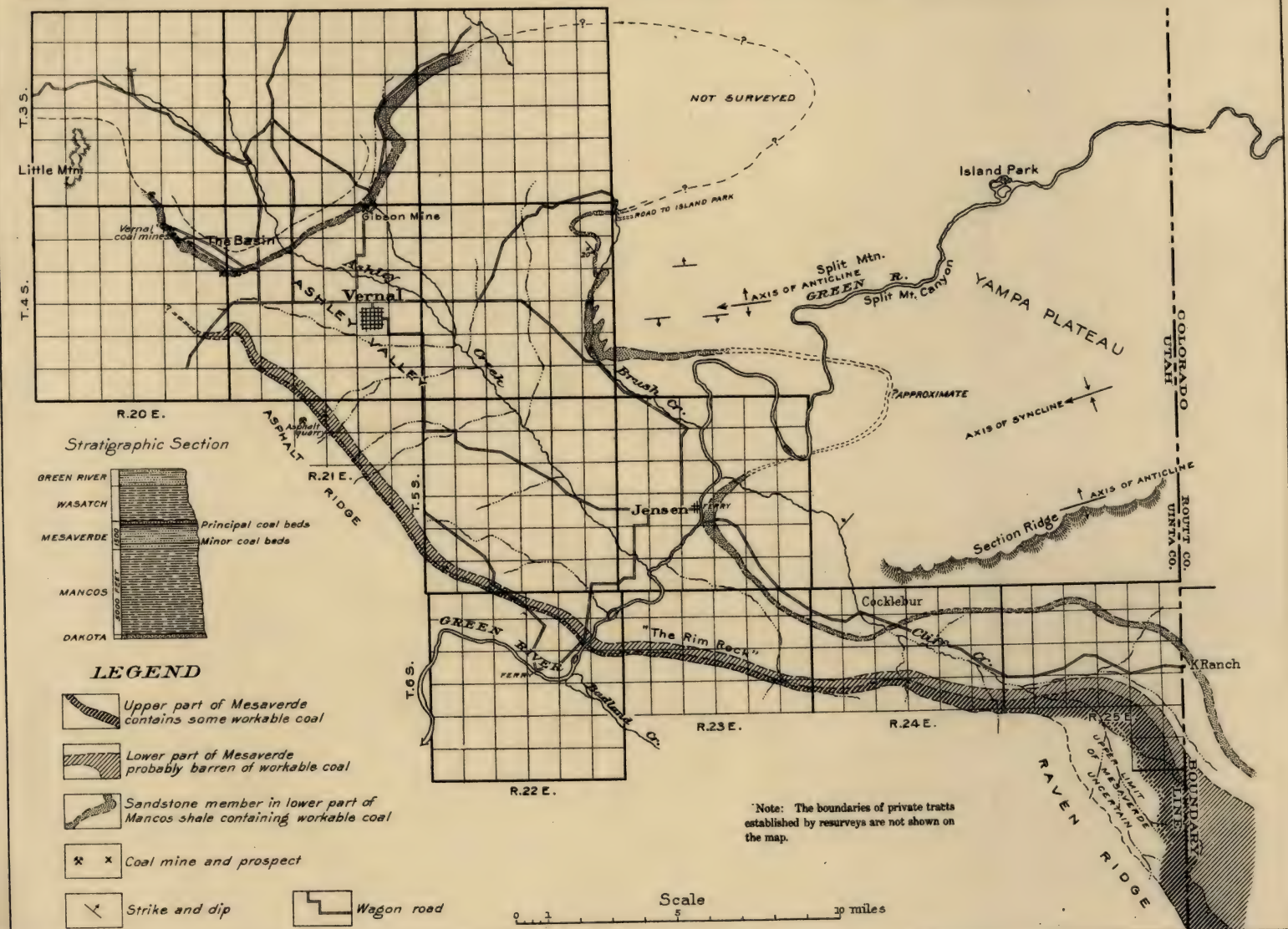
As shown by Pl. XIX, the Mesaverde coals in this part of the Uinta Basin are directly connected with the same group in the White River fields of Colorado, but the State line offers a convenient division line for the separation of the Utah portion, in which these coals have not as yet been shown to be of much importance, at least in comparison with the richer and more extensive deposits of Colorado.

An additionally distinctive feature is shown by the Utah fields in the fact that as the Mesaverde coals become relatively unimportant, older strata at the base of the Mancos shale develop workable beds, which at the present time carry the only coal considered worth exploitation in or near this part of the Green River valley.

MESAVERDE COAL.

Tracing of the Mesaverde formation.—West of the State line the basal sandstones of the Mesaverde are the most conspicuous members of that formation, constituting a rim-rock ridge somewhat analogous





to the "rim rock" of Raven Park. This ridge is very distinct and easily traced to and beyond Green River and the position of the Mesaverde coal beds may be inferred from it, even where they are not actually exposed. As a whole, however, the Mesaverde formation is relatively much thinner in Utah than in Colorado, and the thinning is apparently due to the absence of upper members of the formation which are represented elsewhere. Thus the Wasatch strata unconformably overlying the Mesaverde appear to sink deeper and deeper as they are traced to the west. The coal beds that are commonly found in the upper part of the Mesaverde formation in other fields are probably wanting here. The whole formation, which measures approximately 5,000 feet in the Grand Hogback field and 2,500 feet on Red Wash in Colorado, is probably not more than 1,500 feet thick and possibly less near Green River. In each place the section toward the base of the formation appears to remain practically constant, but the upper beds are beveled off, disappearing one by one toward the west.

Local development of the Mesaverde coal.—Coal is exposed from place to place along these outcrops, and has been mined to a small extent. A bed of coal at least 7 feet thick and possibly thicker has been opened in a gulch about 2 miles south of "Cocklebur," in T. 6 S., R. 24 E., of the Salt Lake base and meridian, and a slope has been run in on the dip of the strata, which is 35° at this place. The mine is 9 or 10 miles from the ferry at Jensen, on Green River, which is the nearest present market for the coal. The product appears to be a very good grade of bituminous coal, well suited for domestic use, but a poor road for hauling has probably hindered the development of the mine.

West of Green River several attempts have been made to mine the Mesaverde coal, but at present all these operations are abandoned. An old mine in T. 5 S., R. 22 E., is situated on the northeast side of a small isolated knob on the western side of the valley lands. This is said to have been opened in 1893 and worked at intervals until about 1904. The coal bed is reported to have broken off at the face, probably along a local fault or slump. The coal at present exposed is 3 feet 5 inches thick, but the whole bed is reported to have been about 5 feet as worked. This coal has the smell of asphaltum or oil, and as it occurs just below the outcrop of an asphaltum deposit, that material has very probably saturated the coal as it has much of the neighboring rock. The coal is said to have caked somewhat when burned, spreading over the grates and forming a heavy clinker, a property possibly due to the asphaltum it contains. It is also reported to have slacked rapidly—within a month after taken from the mine—if left in the open air.

Another prospect about 3 miles southwest of Vernal exposed a small bed of coal which did not appear to be of much importance.

Beyond that point no coal was observed in the Mesaverde rocks, and farther west the formation may be either cut out entirely by the unconformity between the Cretaceous and Tertiary rocks or concealed by some of the Tertiary and later deposits.

MANCOS COAL.

Age.—The older coal of the Vernal field is associated with fossiliferous strata both above and below the workable bed, and collections from these horizons are reported to be distinctive of the Benton shale of other fields. Where a group of sandstones and the contained coal beds form a conspicuous lithologic unit, as they do in most of this Utah field, their outcrop is indicated on the map as far as it has been traced, and it is referred to in the legend of the map and elsewhere in the report as the Mancos coal group.

Position of the outcrop.—The coal group in the lower part of the Mancos shale presents a sinuous outcrop in the vicinity of the Green River valley near Vernal. These beds follow the sharp folds of the older strata of the Uinta Mountain axes as continuous curved ridges, tracing around the ends of the pitching anticlines and into the deep reentrant valleys of the synclines. Only a small portion, considerably less than one-half of the length of outcrop exposed, is known to contain valuable coal. Thus the sandstone beds of this horizon are exposed in the banks of Green River at Jensen, but are not known to contain coal. They are also exposed west of Green River around the foot of Split Mountain. On Brush Creek the coal is of workable thickness at a few places. Very little is known concerning the coal around the northeast end of the Island Park syncline, but it is said to be of small practical value. Along the cropping of this bed north and northeast of Vernal it is or has been mined at a few places along the valley of Brush Creek, but the principal developments are grouped in a locality 7 to 8 miles northwest of Vernal, on the southeast side of Little Mountain.

Character of the bed mined.—The coal bed presents the same or a similar character in the number and thickness of its partings and is doubtless at the same horizon throughout the field. One or two other small beds of coal are reported at various places, but only the large bed has ever been shown to be of value. Most of the accessible mines and prospects were visited and measurements taken of the coal, as well as a set of representative samples for chemical analysis. The results of the analyses are included in the table on pages 314–315. The thickness of the bed and the nature of its partings are well shown in the following table of measurements, which are arranged in the order of their position along the outcrop from northwest to southeast.

Measurement of Mancos coal as mined near Vernal.

Section.	George Gray mine.	Joe Rich mine.	A. N. Timothy mine.	C. C. Rich mine.
	<i>Ft. in.</i>	<i>Ft. in.</i>	<i>Ft. in.</i>	<i>Ft. in.</i>
Coal.....	1 10½	2 3	1 11½	1 6½
Bone.....	11	9	8½	10
Coal.....	7	9½	10	9
Bone.....	7½	5½	3½	4½
Coal.....	10½	11	11½	9
Bone.....	2	3½	5½	4
Coal.....	6½	6½	6	4
Total coal.....	3 10½	4 6	4 3	3 4½
Total bed.....	5 7	6	5 8½	4 11

The roof is white sandstone at each mine; the floor at the Gray and Timothy mines is bone.

The coal bed at the Gibson mine, north of Vernal, that in the prospects near the Pollard mine, on Brush Creek, northeast of Vernal, and that at the Bowen mine, farther south on Brush Creek, east of Vernal, all show much resemblance to the sections given above, especially in the character of bony beds and partings contained, although the actual thicknesses vary considerably from place to place.

Quality of the coal.—As may be seen by reference to the analyses the coal from this field is of very much the same quality and degree of efficiency. It is similar to the average Mesaverde coal of the Meeker district, and is distinctly inferior to the coals of the Newcastle and Glenwood Springs districts. The abundance of bony material in the bed is the chief disadvantage and interferes rather seriously with economical mining.

The variation along the outcrop of the bed is very slight, probably not greater than that which is likely to occur in almost any coal bed. The only apparent exception is found in the mine due north of Vernal, which had not been worked for some time when the sample was taken and the coal of which had evidently deteriorated somewhat by exposure to the air.

The lower limit of efficiency of high-grade bituminous coals, as shown by calorimetric determinations, is approximately 12,000 British thermal units, so that the best of the coals in this region fall just within that class.

Demand and market.—The coal directly available in this field is moderate in amount, especially when compared with the extensive coal fields in the adjacent parts of Colorado. The local demand is already a considerable factor, probably as much so now as it will be later, when the coming of a railroad may open up competition with the larger fields to the east.

HENRYS FORK FIELD.

GENERAL STATEMENT.

Coal has been reported from the vicinity of Henrys Fork in northeastern Utah and southern Wyoming, although very little precise information concerning this field has heretofore been available. About ten days at the close of the season were spent in the field, reviewing the geology and looking up some of the known occurrences of coal.

LOCATION.

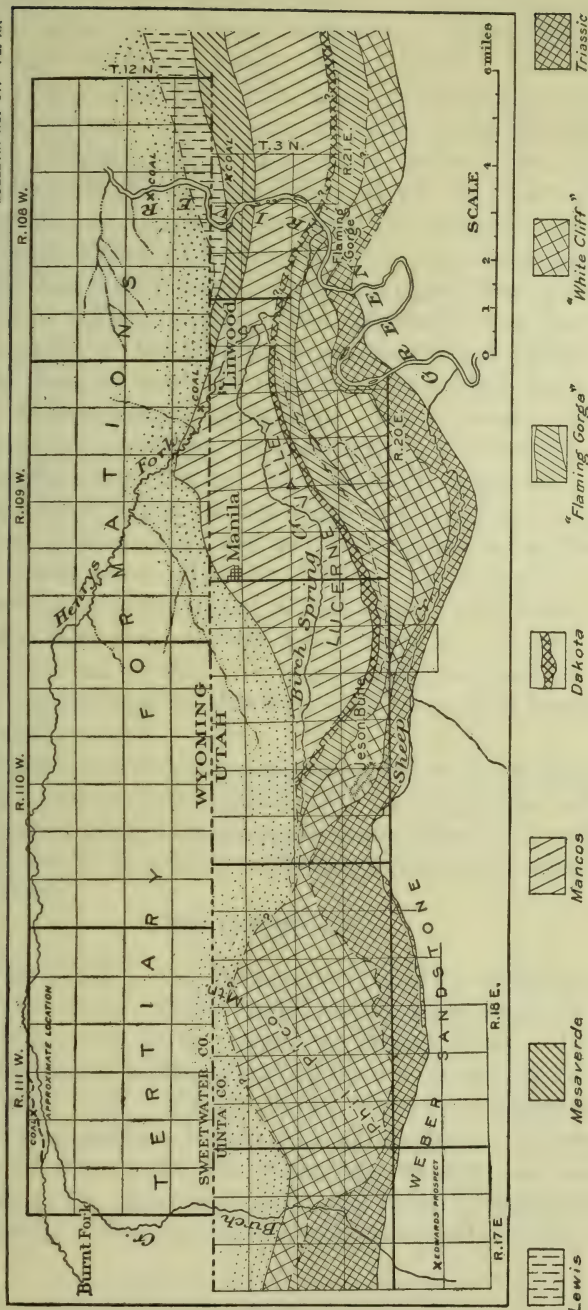
The name, Henrys Fork coal field, has been applied in a rather indefinite way to reported coal croppings in the vicinity of the valley of Henrys Fork, near the junction of that stream with Green River. This district lies along the State line in northeastern Uinta County, Utah, and southern Uinta County, Wyo. It is 40 to 60 miles from the Union Pacific Railroad either at Green River or at Carter, Wyo., the customary mail route going to the latter point.

STRUCTURE.

The field lies north of the Uinta Mountains and is structurally a part of the Green River Basin, or of the Bridger Basin if the larger structural feature be considered as divided by the Rock Springs dome. In general the strata in this field are tilted to the north away from the axes of the Uinta Range. These mountains separate the Henrys Fork field from the Vernal field, just described. Structurally the Henrys Fork field is directly related to the Yampa field, with which its rocks are doubtless connected or continuous, except where they are eroded and covered by the overlap of the Tertiary rocks or are cut out by faulting. The northern flank of the Uinta Range is much broken by faults and as some of these are largely obscured by the Tertiary strata that unconformably overlie the older rocks, the geology of a part of the field is not very clearly revealed.

STRATIGRAPHY.

The Cretaceous formations correspond to those of the Yampa field. Where not faulted out the Mesaverde formation is coal bearing. The relations of the Lewis shale to the overlying Wasatch strata are obscure, but it seems certain that either displacement by faulting or erosional unconformity has obscured the Laramie, at least near Green River, where those beds might be expected, on the east side of the valley above Flaming Gorge.



MAP OF PART OF THE HENRY'S FORK COAL FIELD, UTAH AND WYOMING.

PENNSYLVANIAN (UPPER CARBONIFEROUS) COAL.

An older coal than any heretofore noted in northwestern Colorado was found on upper Birch Creek, tributary to Burnt Fork, which is in turn a branch of Henrys Fork of Green River. This is in sec. 3, T. 2 N., R. 17 E., of the Salt Lake base and meridian, Utah, south of Zeb. Edward's ranch, and occurs in rocks of the same age as the Pennsylvania coal measures.^a The same horizon has been prospected at intervals for several miles along the foothills in this locality, but the coal appears to be of rather uncertain value.

The coal at the Edward prospect is said to have been tested by the Union Pacific Railroad Company, and the report has spread that it proved to be of coking quality. The specimens seen had certainly withstood exposure to the weather in an exceptional manner. Other reports state that the coal has been used in a local forge, where it burned very well and gave a good heat. The exposure seen was in a very unsatisfactory condition for examination. Some pits had been dug in a heavily wooded slope, in a block of strata very evidently slipped from a point higher on the ridge and tilted out of its normal position. The beds are very soft and broken, but nevertheless some of the coal is still hard. The coal bed is very irregular and at no place was more than a few inches of coal visible, although it was confidently stated that the bed was 3 feet thick at the bottom of the pit, which had then caved. No trustworthy estimate of the true character of the bed can be obtained until the coal is found in place and in a normal position.

It is reported that several prospects on Burnt Fork, farther west, show the same bed in place; in these it is much thicker but is not of commercial value, being carbonaceous shale rather than coal.

These beds are of interest as affording an unusual occurrence for the western fields.

MESAVERDE COAL.

As shown on Pl. XX, the Mesaverde formation outcrops at Green River near the center of the broad valley area north of Flaming Gorge, and just north of the mouth of Henrys Fork. Toward the west the formation is evidently cut off by a fault near Linwood post-office, on Henrys Fork. East of Green River the formation may be followed as a long, curved, double ridge extending up the broad strike valley north of the mountains, apparently bending southward and abutting against the mountain mass, and possibly terminated there by another fault. These beds were not examined far east of Green River.

^a Fossils collected in the prospect pit were examined by G. H. Girty, who has made the age determination and identified the following forms: *Fenestella*, 2 sp.; *Lingula*? sp.; *Spirifer rockymontanus*; *Pleurophorella costata*?; *Edmondia* aff. *gibbosa*; *Aviculipecten hertzeri*?; *Aviculipecten* sp.; *Naticopsis* sp.

A well-exposed section was found near the east bank of the river at the mouth of Spring Creek, about one-half mile southwest of the 289 milepost on the Utah-Wyoming State line. Here the Mesaverde formation contains many massive sandstones and intervening shale bodies, which are very similar in character to the same formation in the Yampa field. The whole formation was not examined in detail, but coal was found in it at several horizons. A small amount of prospecting uncovered some beds at least 5 feet thick, and local reports state that the coal has been taken out at some point west of the river for use at the ranches in the valley.

Opposite Linwood post-office, about one-fourth mile north of Henrys Fork, two thick beds of coal are exposed in nearly vertical position. These beds have been prospected somewhat but have never been worked to any considerable extent. The following section was measured at this place:

Section of coal-bearing strata north of Linwood, Utah.

	Ft.	in.
Sandstone, coarse, yellowish, flaggy, and thin bedded.....	15	
Coal, apparently good, without partings.....	8	9
Shale, blue and gray, fine.....	20	
Coal, apparently good, without partings.....	10	
Bone, irregular bed.....	1	
Sandstone, fine grained, clayey, white.....	20+	
	74	9

The strike of the beds is N. 67° W. and the dip 80° to 85° S. The outcrop of this bed splits up within less than 200 yards to the west, and the bed changes in character, becoming chiefly a brown and gray shale with coal streaks. Toward the east the bed follows the course described for a few hundred feet, then bends abruptly south and disappears under an upper terrace level capped by consolidated river deposits. In the next gulch to the east, one-fourth mile or so away, beds of soft black shale, evidently representing the same horizon, have been prospected. Although resembling coal somewhat in appearance, the material is merely a dark clay shale. These beds have been filed on as coal land from time to time, but the filings have always been allowed to lapse without making final proof.

As these beds occur along a line of evident structural displacement, probably a fault of considerable magnitude, it is not certain to what formation they may properly be assigned. The inclosing beds resemble the Mesaverde strata, and their position overlying the Mancos shale suggests that they belong to that formation. Coal is also found in the overlying Tertiary strata, some of which might not be easily distinguished from the Mesaverde.

TERTIARY COAL.

Coal beds in the Tertiary strata have been noted at a number of localities along the north side of Henrys Fork. Outcrops are reported along the bluff bordering that stream for a distance of several miles east of Burnt Fork, Wyo., and the coal is probably continuous for a still greater distance, although no further information on this point has been obtained.

Some exposures of these beds were examined 3 or 4 miles east of Burnt Fork post-office, along a road in a little gulch leading up to the mesa, less than one-fourth mile from the creek and opposite the Mass ranch. The coal is exposed at several horizons. A coal bed near the lower end of the gulch measured 2 feet 10 inches, as shown in natural outcrop, and although considerably weathered, much of it was a clear, glossy black. The roof is a sandy and calcareous shale, alternately thick and thin bedded. The floor is a brown, woody clay, which is evidently softened by exposure. The beds are nearly horizontal, the dip being very low toward the north. The bed is evidently continuous for some distance, as its croppings can be plainly traced around the hillside. The coal is doubtless subbituminous, although this statement is no more than a rough estimate based on the appearance of the weathered exposure.

On another bed exposed 100 yards or so farther up the gulch a small amount of digging uncovered 2 feet of coal, but the bed is doubtless somewhat thicker. A prospect drift had been dug at this place but is now wholly caved. Some very perfect impressions of a symmetrically coiled spiral gasteropod were collected from the roof of this coal bed, but unfortunately they do not fix the geologic age of the strata, except to indicate that they belong to the fresh-water Tertiary. The coal-bearing beds are very probably of Wasatch age, as they are succeeded by strata which resemble the Green River shales and sandstones, and these in turn are overlain by undoubted Bridger beds with their vivid green banding.

Other coal beds in Tertiary strata were observed at the bank of Green River, north of the mouth of Henrys Fork. This locality is about 1.3 miles N. 5° E. of the 290 milepost on the Utah-Wyoming line. The coal was very poorly exposed and could not be shown to be of workable thickness without further development. A collection of fossils from neighboring rocks contain some fresh-water shells resembling clams and gasteropods elsewhere found in the Wasatch, but the same species also occur in later Eocene formations of this region.

SUMMARY OF THE HENRYS FORK FIELD.

Coal is rather widely distributed both stratigraphically and geographically in the Henrys Fork valley. Little effort has yet been made to develop or even to prospect the beds, probably owing to the fact that timber is plentiful and not hard to get. With the possible exception of the beds at Linwood, no coal beds of unusual thickness or importance are known to exist there. Many of the reported beds are probably thin, and the Tertiary coal is of a rather light weight (subbituminous) variety. The most promising part of the field is thought to be in Spring Creek valley east of Green River, just north of Flaming Gorge, in the Mesaverde rocks that are exposed in that locality. It must be admitted, however, that the examination of this section of strata was too incomplete to warrant any estimate of the quality or total quantity of the coal.

ANALYSES.

The character of the coal from the several fields discussed in this paper is indicated by the subjoined analyses, which were made at the Survey fuel-testing plant, Pittsburg, Pa.

Analyses of coal samples from the Uinta Basin, Colorado and Utah.

[F. M. Stanton, chemist in charge.]

Name of coal field.....		Yampa.				Lower White River.			Vernal.	
Geologic age or formation..		Post-Laramie.	Mesaverde.			Mesaverde.			Mancos.	
Laboratory No.....		5514	3463	3461	3462	5516	5519	5520	5511	5753
Sample as received:										
Prox.	Moisture.....	17.46	14.65	13.31	12.31	10.96	11.39	14.10	8.46	8.64
	Volatile matter.....	28.21	34.73	35.18	36.17	33.13	32.36	31.83	34.32	36.42
Ult.	Fixed carbon.....	47.17	44.48	46.53	45.40	47.05	48.44	48.81	47.17	47.62
	Ash.....	7.16	6.14	4.98	6.12	8.86	7.81	5.26	10.05	7.32
Ult.	Sulphur.....	1.14	.99	.90	1.10	.73	.45	.38	1.58	1.25
	Hydrogen.....	5.66	5.80		5.75		5.48	5.65	5.33	5.57
Ult.	Carbon.....	56.33	60.07		62.72		62.64	62.15	62.79	65.55
	Nitrogen.....	.79	1.10		1.16		1.14	1.06	1.00	1.09
Ult.	Oxygen.....	28.92	25.90		23.15		22.48	25.50	19.25	19.22
	Calories.....	5,391	5,869		6,163	5,939	5,965	6,075	6,250	6,600
British thermal units.....		9,704	10,564		11,093	10,690	10,737	10,935	11,250	11,880
Loss of moisture on air drying.....		5.70	5.30	4.50	4.00	3.20	3.10	4.80	2.90	2.60
Air-dried sample:										
Prox.	Moisture.....	12.47	9.87	9.23	8.66	8.02	8.55	9.77	5.73	6.20
	Volatile matter.....	29.92	36.68	36.84	37.68	34.22	33.40	33.43	35.34	37.39
Ult.	Fixed carbon.....	50.02	46.97	48.72	47.29	48.61	49.99	51.27	48.58	48.89
	Ash.....	7.59	6.48	5.21	6.37	9.15	8.06	5.53	10.35	7.52
Ult.	Sulphur.....	1.21	1.05	.94	1.15	.75	.46	.40	1.63	1.28
	Hydrogen.....	5.33	5.50		5.53		5.30	5.38	5.16	5.42
Ult.	Carbon.....	59.74	63.43		65.33		64.65	65.28	64.66	67.30
	Nitrogen.....	.84	1.16		1.21		1.18	1.11	1.03	1.12
Ult.	Oxygen.....	25.29	22.38		20.41		20.35	22.30	17.17	17.36
	Calories.....	5,717	6,197		6,420	6,135	6,156	6,381	6,437	6,776
British thermal units.....		10,291	11,155		11,555	11,043	11,080	11,486	11,586	12,197
Thickness of coal bed.....		<i>Ft. in.</i> 11 4	<i>Ft. in.</i> 20 3	<i>Ft. in.</i> 9	<i>Ft. in.</i> 7 10	<i>Ft. in.</i> 4 2	<i>Ft. in.</i> 11 11	<i>Ft. in.</i> 11 11	<i>Ft. in.</i> 6 7	<i>Ft. in.</i> 6 7
Thickness of part sampled..		11 4	5 7	7	5 5	3 8	11 11	7 4	3 10	3 9

Analyses of coal samples from the Uinta Basin, Colorado and Utah—Continued.

Name of coal field.....	Vernal.								
Geologic age or formation...	Lower part of Mancos.								
Laboratory No.....	5512	5509	5754	5755	5513	5510	5515	5517	5518
Sample as received:									
Prox. Moisture.....	8.64	8.65	8.23	8.64	8.21	8.82	9.43	11.66	10.22
Prox. Volatile matter.....	36.09	36.16	35.69	36.74	34.30	36.60	32.77	34.40	32.68
Prox. Fixed carbon.....	47.21	48.19	45.77	46.67	45.70	48.33	44.94	44.50	44.85
Prox. Ash.....	8.06	7.00	10.31	7.95	11.79	6.25	12.86	9.44	12.25
Ult. Sulphur.....	1.39	1.63	1.26	2.09	1.76	1.66	1.93	1.92	.77
Ult. Hydrogen.....	5.57	5.51	5.50	5.75	5.39	5.72	5.12	5.64	5.31
Ult. Carbon.....	64.10	65.10	63.52	65.68	61.03	65.11	57.81	59.16	60.04
Ult. Nitrogen.....	1.04	1.09	1.00	1.01	.98	1.09	.90	.92	.96
Ult. Oxygen.....	19.84	19.67	18.41	17.52	19.05	20.17	21.38	22.92	20.67
Calories.....	6,434	6,466	6,346	6,538	6,152	6,571	5,759	5,875	5,936
British thermal units.....	11,581	11,639	11,423	11,768	11,074	11,828	10,366	10,575	10,685
Loss of moisture on air drying.....	2.80	2.60	2.30	2.50	2.50	2.90	3.00	4.40	3.30
Air-dried sample:									
Prox. Moisture.....	6.01	6.21	6.07	6.30	5.86	6.10	6.63	7.59	7.16
Prox. Volatile matter.....	37.13	37.12	36.53	37.68	35.18	37.69	33.78	35.98	33.79
Prox. Fixed carbon.....	48.57	49.48	46.85	47.87	46.87	49.77	46.33	46.55	46.38
Prox. Ash.....	8.29	7.19	10.55	8.15	12.09	6.44	13.26	9.88	12.67
Ult. Sulphur.....	1.43	1.67	1.29	2.14	1.81	1.71	1.99	2.01	.80
Ult. Hydrogen.....	5.41	5.36	5.36	5.61	5.24	5.56	4.94	5.39	5.11
Ult. Carbon.....	65.95	66.84	65.02	67.37	62.60	67.05	59.59	61.88	62.09
Ult. Nitrogen.....	1.07	1.12	1.02	1.04	1.00	1.12	.93	.96	.99
Ult. Oxygen.....	17.85	17.82	16.76	15.69	17.26	18.12	19.29	19.88	18.34
Calories.....	6,619	6,639	6,495	6,706	6,310	6,767	5,937	6,145	6,138
British thermal units.....	11,915	11,900	11,692	12,070	11,358	12,181	10,687	11,061	11,050
Thickness of coal bed.....	<i>Ft. in.</i> 5 11	<i>Ft. in.</i> 5 11	<i>Ft. in.</i> 5 8½	<i>Ft. in.</i> 5 8½	<i>Ft. in.</i> 4 11	<i>Ft. in.</i> 4 11	<i>Ft. in.</i> 7 2½	<i>Ft. in.</i> 7 2½	<i>Ft. in.</i> 7 2½
Thickness of part sampled..	1 2½	3 ½	1 3	2 7	1 1	2 3½	1 2	3 6½	1 9

5514. Sec. 28, T. 8 N., R. 93 W.

3463. Sec. 31, T. 7 N., R. 93 W.

3461. Sec. 31, T. 7 N., R. 93 W.

3462. Sec. 31, T. 7 N., R. 93 W.

5516. White River, at the mouth of Red Wash, sec. 11, T. 2 N., R. 101 W.

5519, 5520. Raven Park, sec. 14, T. 1 N., R. 102 W. Sample 5519 represents coal not quite so fresh as sample 5520.

5511, 5753. NE. ¼ SE. ¼ sec. 3, T. 4 S., R. 20 E. Sample included all of the marketable coal of the section exposed. Some of the coal is divided into two grades, the top and bottom benches being sold as first grade and the intermediate coal as second grade.

5512, 5509. W. ¼ SW. ¼ sec. 2, T. 4 S., R. 20 E. Sample 5512 represents lower two benches, marketed as second-grade coal. Sample 5509 represents upper two benches, marketed as first-grade coal.

5754, 5755. Lot 10, SW. ¼ sec. 2, T. 4 S., R. 20 E. Sample 5754 represents lower two benches, marketed as second-grade coal. Sample 5755 represents upper benches, marketed as first-grade coal.

5513, 5510. Lots 1 and 2, NW. ¼ sec. 11, T. 4 S., R. 20 E. Sample 5513 represents lower two benches, marketed as second-grade coal. Sample 5510 represents upper two benches, marketed as first-grade coal.

5515, 5517, 5518. NE. ¼ NW. ¼ sec. 2, T. 4 S., R. 21 E. Sample 5515 represents lower 14 inches of the top bench of good, hard coal 22 inches thick, the rest being bony. Sample 5517 represents a middle bench composed of a very soft, flaky coal; reported to be of coking quality. Sample 5518 represents lower bench, which is bright black and hard, and seemed to be the best coal in the bed.

THE GRAND MESA COAL FIELD, COLORADO.

By WILLIS T. LEE.

INTRODUCTION.

LOCATION OF THE FIELD.

The Grand Mesa coal field is located on the southern rim of the Uinta coal basin, which lies partly in northwestern Colorado and partly in Utah. It derives its name from Grand Mesa, a high tableland between Grand and Gunnison rivers. The coal beds underlie the mesa and outcrop along the south and west sides. They extend westward into the Book Cliffs field, north of Grand Junction,^a and eastward into the Anthracite-Crested Butte region,^b long known for its anthracite coal, and thence northward along the Grand Hogback, recently described by Gale.^c

PURPOSE OF THE INVESTIGATION.

The investigation of this field was undertaken for the purpose, first, of ascertaining the relations of the coal-bearing rocks to other formations; second, of segregating the coal land from the noncoal land and classifying it according to the legal subdivisions of the General Land Office; and, third, of determining the thickness of the coal beds, the character and quality of the coal, its accessibility with reference to topography and its location with reference to lines of transportation. The economic results of the investigation are summarized in this paper. Details and the results of scientific importance will be found in a more comprehensive paper to be published later as a separate bulletin.

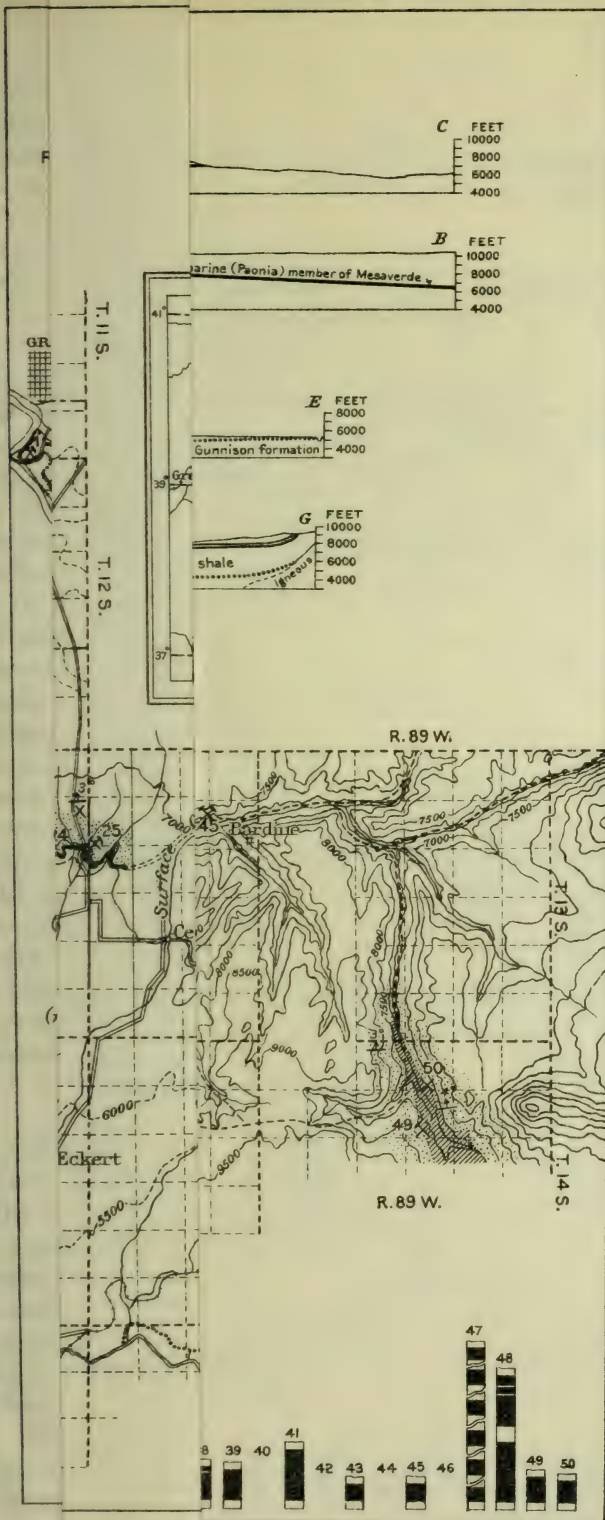
METHODS OF WORK.

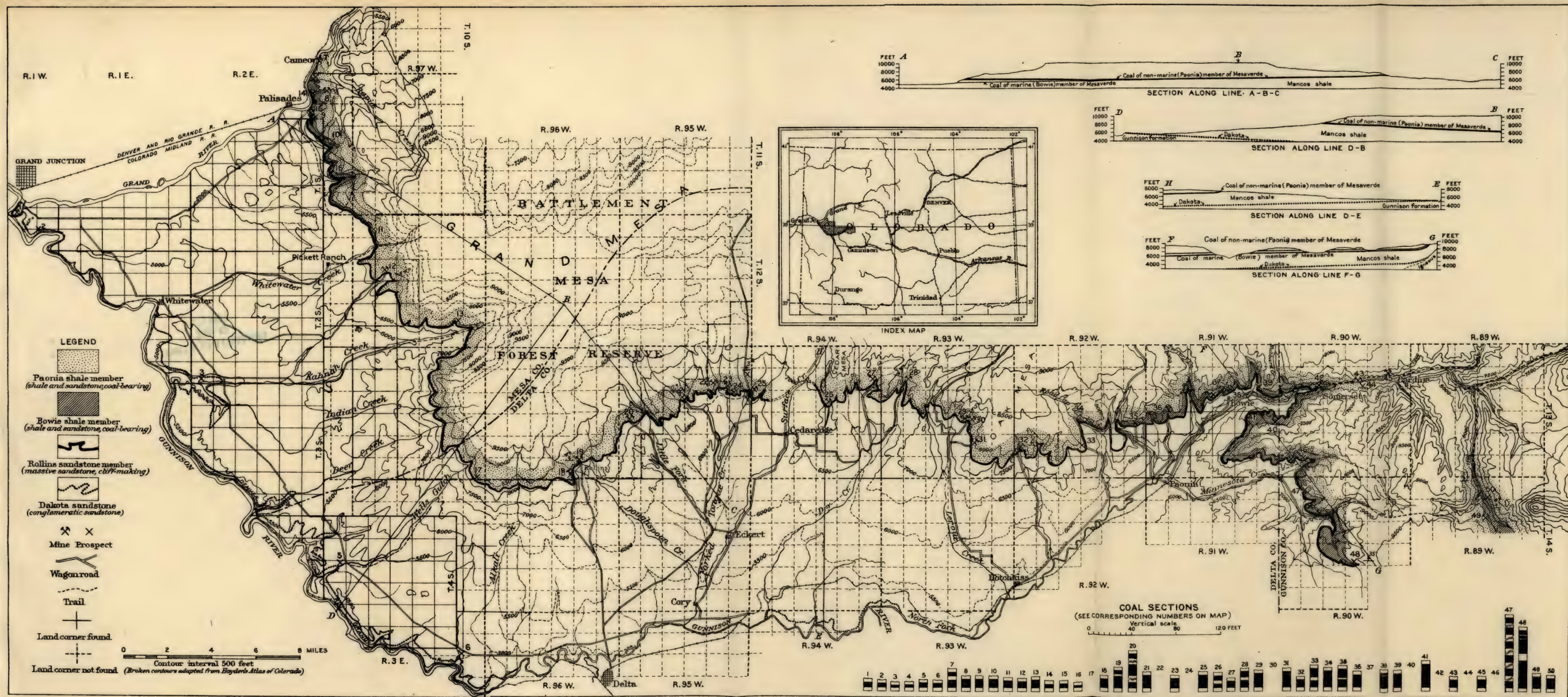
The Grand Mesa field is comparatively free from complicated structures, and the geologic work consisted principally in determining the ages and areal distribution of the sedimentary rocks. Samples

^a Richardson, G. B., The Book Cliffs coal field, between Grand River, Colorado, and Sunnyside, Utah; Bull. U. S. Geol. Survey No. 316, 1907, pp. 302-320.

^b Eldridge, G. H., Anthracite-Crested Butte folio (No. 9), Geologic Atlas U. S., U. S. Geol. Survey, 1894.

^c Gale, H. S., Coal fields of the Danforth Hills and Grand Hogback in northwestern Colorado: Bull. U. S. Geol. Survey No. 316, 1907, pp. 264-301.





were collected from the various coal openings for analysis and for comparison with coal from other fields, and data were collected concerning the characteristics of the coal that might affect its market value—such, for example, as its tendency to slack and its ability to coke. The accessibility of the coal is indicated on the accompanying map (Pl. XXI), which shows the general surface configuration of the field by means of contour lines.

In accordance with the object of this work, an attempt was made to map and classify the land by townships, ranges, and sections. As the work progressed, however, it was found that the land surveys were not adequate for this purpose. In the lowlands at the west end of the field almost all the corners were found, but in the central and eastern parts few could be located in the lowlands and practically none in the highlands, where the coal occurs. The presence of corners is indicated on the accompanying map by solid lines; the dotted lines indicate that none was found.

In the absence of Government corners near the coal, some other method of determining location had to be devised. In many places, because of the precipitous character of the country, it was impracticable to traverse the outcrop of the coal, and its location was determined principally by triangulation from such corners as could be found; many of these were several miles away. This method might have given satisfactory results if the corners used in triangulation had been accurately located, but that many of them were not became evident when locations of certain points made from one set of corners failed to coincide with locations of the same points made from other corners. Some of the inaccuracies are traceable to the original surveys and others to the attempts of local surveyors to reestablish lost corners or to establish new ones where they supposed the original corners should be. For these reasons, although the map is approximately correct, no final classification of the land can be made.

ACKNOWLEDGMENTS.

The writer was assisted in the field by Charles S. Blair, who spent part of the time in examining the coal and part of it in constructing the map, and by Russell R. Bryan, whose time was devoted wholly to mapping. The office work of preparing the map for publication was done mainly by A. J. Hazlewood. The writer also wishes to acknowledge his indebtedness to Alex Bowie, S. G. Porter, and other mine owners for aid and many courtesies during the fieldwork, and to J. W. Curtis, of Delta, who furnished much information regarding the land surveys.

The invertebrate fossils collected during the investigation have been identified by T. W. Stanton and the fossil plants by F. H. Knowlton. On their identifications depend the correlations made in this paper.

SURFACE FEATURES.

The Grand Mesa coal field is characterized by a very uneven surface. In the western and southern parts a broad belt of comparatively low relief borders a flat-topped table-land that rises to an altitude of more than 10,000 feet above the sea, or a mile vertically above the lowlands. In the middle-ground, where the coal crops out there is a belt of rugged country that differs in character from place to place according to the underlying rocks. Below the coal the rock consists of soft shale which is covered in many places with fragments of basalt derived from the sheet that caps the mesa. The shale is carved by erosion into broad, tongue-shaped mesas and badlands consisting of sharp irregular ridges and V-shaped ravines. Above the coal there are hard sandstones that form precipitous cliffs in some places and steep wooded or débris-covered slopes in others.

Near the east end of the field the surface configuration differs from that to the west in the absence of lowlands and the presence of high mountains that rise above the surface of the mesa. Narrow canyons have been cut by the streams to depths of 2,000 feet or more in the hard sandstone that overlies the coal. The highlands are covered more or less completely with timber, consisting principally of cedar in the western part of the field, and spruce, pine, and other forest trees farther east. In many places the cedars form dense thickets and the trees grow to considerable size, but few of the trunks are sound and they do not make good mine props. However, the pine and spruce trees that grow in considerable abundance in the canyons and on the mountain sides in the eastern part of the field are suitable for mining purposes.

The highlands have further potential importance in connection with the coal, inasmuch as they furnish the only supply of water available in many places. Near Palisades and Somerset the rivers furnish all water necessary for domestic purposes and for such coal washeries as may be needed, but in the greater part of the field the coal is far above the river level and the only available water is that supplied by numerous small streams from Grand Mesa. These highland waters are of good quality and with proper manipulation they can be delivered in any part of the field in quantities sufficient for mining purposes. The waters that issue from the shale below the coal or that flow over it are highly charged with salts that render them unfit for domestic use.

The means of approach to the coal are shown on the accompanying map (Pl. XXI) and require little comment. The main line of the Denver and Rio Grande Railroad crosses the coal outcrop at the northern border of the field and a branch of this road runs to the

coal at Somerset, on the North Fork of the Gunnison. At no point within the field does the coal crop out more than 15 miles from a railroad in operation. However, much of the coal can not now be reached by wagon. No roads and but few trails cross the outcrop between Palisades and the Kuhnley mine (No. 18, Pl. XXI), a distance of more than 25 miles. East of the Kuhnley mine wagon roads have been built to the coal in many places, but on the North Fork there is no wagon road east of Bowie.

GEOLOGY.

STRATIGRAPHY.

The accompanying generalized section shows the character and succession of the rocks in this field.

Generalized section of rocks in the Grand Mesa coal field, Colorado.

System. Group.	Formation.	Member.	Thickness (feet).	Characteristics.	Economic value.
Tertiary.	Green River.		200-1,800	White friable sandstone and clay shale, capped by basalt.	
	Ruby (probably Washatch).		500-2,000	Conglomeratic sandstone and shale, varicolored. In the eastern part of the field the rocks are mainly red and conglomeratic beds are numerous. The basal conglomerate consists principally of quartz and chert pebbles and the higher ones of various crystalline, metamorphic, and extrusive rocks. In the western part of the field lighter colors prevail and the rocks are finer in texture.	
	Unconformity.				
	Ohio Creek.		100	White friable conglomeratic sandstone, containing pebbles of quartz, jasper, and igneous rock.	
Cretaceous.	Unconformity.				
			2,000±	Gray quartzose sandstone, varying from soft and friable to hard and cliff making, and shale with plant remains and shells of fresh-water invertebrates.	Coal of doubtful value near the center of the section in the eastern part of the field.
		Paonia shale.	400+	Shale, carbonaceous in places, and sandstone, with plant remains and shells of fresh-water invertebrates.	Coal bearing throughout the field; one bed of workable thickness at west end and four or more at east end.
	Mesaverde.	Bowie shale.	425±	Dark-colored shale and gray sandstone, containing marine and brackish-water invertebrates. (Absent from central part of field.)	Coal bearing; one workable bed at west end of field and nine or more at east end. Coal much better than the fresh-water coal above, ranging in quality from bituminous to anthracite.
		Rollins sandstone.	100±	White cliff-making sandstone containing marine invertebrates.	

The determination of the geologic age of the formations in the Grand Mesa coal field is based on paleontologic and stratigraphic evidence. The generalized section embodies the conclusions of the paleontologists regarding the geologic age and also the results of the field studies with respect to the character and relations of the various formations.

The Gunnison formation consists of variegated shale and sandstone, and is exposed in the Grand Mesa field only in the canyon of Gunnison River. It underlies the Dakota sandstone, a more resistant formation, which by its superior hardness maintains the steep cliffs and inclined mesas that border the river. The oldest coal of the Grand Mesa field occurs between the conglomeratic sandstone that is here referred to the Dakota and the overlying Mancos shale. It is locally known as the "Dakota coal," on the supposition that it occurs in the Dakota sandstone, but there are reasons which will be discussed in the more detailed description to be published later for referring it to the Mancos rather than to the Dakota. The coal outcrops between Grand Junction and Delta, as indicated on Pl. XXI, and again near the mouth of Gunnison Canyon east of Delta, but so far as is now known it is not of commercial value and is not here included among the coals of economic importance.

The Mancos is a marine formation and contains only the so-called "Dakota coal." The lower part corresponds to the Benton formation of other fields and the top to the lower part of the Pierre, as shown by fossil evidence.

The Mesaverde formation lies conformably upon the Mancos shale and is the only important coal-bearing formation in this field. The lower part of it was called "Fox Hills" and the upper part "Laramie" by the geologists of the Hayden Survey,^a and other geologists have followed them in referring the coal to the Laramie. However, a study of the fossils, in connection with the stratigraphy of western Colorado, proves that it is much older than the Laramie, and the entire series of coal-bearing rocks in this field is now referred to the Mesaverde formation, originally named by Holmes,^b in southwestern Colorado. Where the full section is exposed the Mesaverde is separated from the Laramie by a marine formation known as the Lewis shale, but in the Grand Mesa field there is no representative of the Lewis or of the Laramie beds. The sedimentary rocks of Tertiary age rest unconformably upon the Mesaverde.

In this field the upper part of the Mesaverde does not contain coal in beds thick enough to be of commercial value and need not be described. The lower part contains all the workable coal so far as

^a Hayden, F. V., *Atlas of Colorado*, 1877.

^b Holmes, W. H., *Ninth Ann. Rept. U. S. Geol. and Geog. Survey Terr.*, 1875, pl. 35.

known and is separable into three members of economic importance. These will be fully described in the detailed report on this region, which is practically completed and will soon appear as a bulletin of the United States Geological Survey.

The lower member is a white, massive, cliff-making sandstone that is persistent throughout the field and marks the base of the coal-bearing rocks. The name Rollins sandstone, derived from the Rollins mine, north of Delta, where the sandstone forms a conspicuous cliff, has been adopted for this member.

Above this basal sandstone at either end of the field is a coal-bearing member that consists mainly of shale and beds of relatively hard and high-grade coal and contains shells of marine and brackish-water invertebrates. The name Bowie shale, from Bowie, a mining town on the North Fork of the Gunnison, where the shale is typically exposed, has been adopted for this member.

The third member of economic importance is the Paonia shale, so named from Paonia, a town on the North Fork of the Gunnison. It consists principally of shale with beds of relatively soft and low-grade coal and is characterized by plant remains and shells of fresh-water mollusks. The Paonia shale member rests upon the Bowie shale member with apparent conformity at the east end of the field, but unconformably upon the Rollins sandstone member in the central part. At the west end the Bowie shale member again appears, but there is an erosional unconformity between it and the overlying Paonia member.

These two coal-bearing members of the Mesaverde formation differ notably in physical character at the west end of the field. The Bowie member there consists principally of massive sandstone and thick beds of shale, with one bed of coal at the base. The Paonia member consists mainly of carbonaceous shale and thin beds of sandstone, with one thick bed of coal at the base and several thin beds above. At the east end of the field the lithologic distinction between these two members is not so pronounced, as both contain carbonaceous shale and sandstone in alternating layers, with beds of coal at many horizons. However, the two are usually separated by a sandstone that contains marine shells. The line of separation between the Bowie member and the Paonia member, although in places difficult to determine in the field, is economically important because of the difference in the quality of the coal, the upper coals being soft and lignitic and the lower coals bituminous and, locally, of coking quality.

No coal of commercial importance is known above the Paonia shale, and the overlying rocks are only of negative importance in the present consideration, as they cover the coal to depths of several thousand feet.

STRUCTURE.

The Grand Mesa coal field is a part of the southern rim of the Uinta coal basin of northwestern Colorado and eastern Utah. The rocks, inclining toward the lowest part of the basin, dip in a general northeasterly direction except near the east end of the field, where the dip is more to the north or northwest. The degree of dip varies locally, but the average is about $2\frac{1}{2}^{\circ}$. However, it is usually greater than this near the outcrop, owing to local upturning of the exposed edges of the strata. Near the east end of the field the structure has been complicated by the intrusion of great masses of igneous rock and the formation of laccolithic mountains, but within the area mapped the coal has not been greatly disturbed. A few small faults have been encountered in the mines, but so far as reported nowhere has the mining been seriously hindered by any disturbed condition of the beds. The only displacements of consequence that have been noted are at the mouth of Black Canyon of the Gunnison east of Delta and in the vicinity of Surface Creek. At the mouth of Black Canyon a local fold has been formed and for a short distance the sedimentary rocks are vertical. The coal-bearing beds east of Surface Creek are apparently about 400 feet higher than the same beds 2 miles farther west. The intervening space is covered with stream deposits and it could not be ascertained whether the displacement is due to faulting or to warping. However, the disturbance is in a locality where the least amount of coal occurs and apparently has no important bearing on the development of the field.

THE COAL.

GEOGRAPHIC DISTRIBUTION.

Aside from the coal at the base of the Mancos formation, which is not of commercial value, the outcrop of the coal in the Grand Mesa field forms a long, sinuous band in the western and southern slopes of the mesa, and can be best described by districts, as follows: (1) The Gunnison district lies between Grand Junction and Delta and includes only the Mancos coal; (2) the Palisades district extends from Grand River to the southern point of Grand Mesa; (3) the Rollins district extends from the southern point of the mesa eastward to Paonia, and (4) the Somerset district includes the coal east of Paonia.

GUNNISON DISTRICT.

The coal of the Gunnison district occurs in the zone of carbonaceous shale at the base of the Mancos formation and outcrops in the bluffs north of Gunnison River. It was formerly mined to some extent near Grand Junction (No. 1^a), but the openings are now abandoned. It is still mined for local use in Wells Gulch (No. 5), and has been

^a Numbers refer to coal sections and locations on Pl. XXI.

opened at several other places. The coal beds are irregular in thickness, ranging within short distances from a few inches to a maximum of slightly less than 4 feet. Near Grand Junction there are four beds, as shown in the following section:

Section of coal-bearing rocks at the junction of Grand and Gunnison rivers, Colorado.

Shale, Mancos, containing at the base thin layers of quartzitic sandstone with fossils of Benton age.	Ft.	in.
Coal.....	1	6
Shale.....		4
Coal.....	2	8
Shale, carbonaceous, with thin beds of coal.....	2	4
Shale, sandy.....		6
Coal.....		10
Shale, sandy.....		8
Coal.....		3
Sandstone, coarse, quartzitic, thin bedded.....		8
Shale, carbonaceous, with thin beds of coal.....		3
Sandstone, conglomeratic (Dakota).....		20
	55	8

Farther east, at locality No. 2, the largest bed is 3 feet thick, but at Kahnah Creek (No. 3) and at Deer Creek (No. 4) less than 1 foot of coal was found. Still farther to the east, at Wells Gulch (No. 5), the coal is 3 feet 4 inches thick at the outcrop, but only 1 foot 6 inches 175 feet from the opening. At locality No. 6 the coal is 3 feet thick.

The coal is black, bituminous, of dull luster, and bony in many places, and it does not burn readily, probably because of long exposure. A sample for analysis (No. 5530 in table, p. 333) was taken near Grand Junction, and represents the upper two beds of the section, the 4 inches of shale separating them being discarded. The face of the bed was cleared in order to procure fresh coal, but the results of the analysis indicate that the coal is very poor. A sample was taken also near the east end of the district, from a face which was apparently not affected by weathering, and the analysis (No. 5534) indicates a coal of good quality. However, the beds are not thick enough to be included among those of economic importance.

PALISADES DISTRICT.

Upper coals.—The upper coal beds of the Palisades district occur at the base of the Paonia or nonmarine member of the Mesaverde formation, and extend with uniform thickness across the district. The coal-bearing part of the Paonia is 225 feet thick and contains eight or more beds of coal. The lowest bed, 7 feet thick, is the most valuable, none of the others, so far as known, being more than 3 feet thick. The coal is easily accessible for a distance of 3 miles along the river, east of Palisades, but for the next 4 miles to the south it outcrops high in the steep cliffs. Still farther south, although the coal occurs higher in the cliffs, it is more readily accessible because of the graded

slopes leading up to it; but even here at only one place, the Patterson mine (No. 12), can the coal be reached by wagon. The lowest coal bed of this group is the same as the one worked at Cameo and described by Richardson.^a Several openings have been made in this coal bed, but in only one, the Bailey mine (No. 7), was work being done at the time of the investigation. A considerable amount of work has been done at several of the openings, but none of them are equipped with machinery or trackage.

The coal is black and fine grained, with vitreous to dull luster, banded texture, and conchoidal fracture. It is comparatively soft and slacks on exposure. It shows a slight tendency to coke, the fragments adhering in the forge; but tests on coal from the Patterson mine are reported as failing to produce coke. The coal bed is regular in thickness, uniform in character, and contains only a small amount of foreign material.

Lower coal.—The lower coal of the Palisades district occurs at the base of the Bowie or marine coal-bearing member of the Mesaverde formation, about 450 feet below the upper coal. There is only one bed of coal in this member. It is 3 feet 4 inches thick at the north end of the district, where it is mined for the local market at the Stokes mine (No. 14), but it thins out a few miles south of Palisades. The coal is harder and cleaner than the upper coal and does not slack readily on exposure. Its quality is regarded as somewhat superior to that of the upper coal, but mining operations are difficult on account of the thinness of the bed.

Sections.—The sections given in the subjoined table show the character of the coal beds in the Palisades district:

Sections of coal beds in the Palisades district, Grand Mesa coal field, Colorado.

UPPER COAL (PAONIA SHALE MEMBER, OR FRESH-WATER MESAVERDE).

No. on Pl. XXI.	Name and location of mine.	Section.	Ft. in.	No. on Pl. XXI.	Name and location of mine.	Section.	Ft. in.
7	Bailey; NW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 34, T. 10 S., R. 98 W.	Sandstone, massive. Shale, sandy..... Coal, impure..... Shale, sandy..... Coal..... Shale.	 5 3 4 6 2 18 2	9	Prospect near De Rush mine; sec. 11, T. 11 S., R. 98 W.	Shale. Coal..... Shale, sandy.....	 7 5 12
8	Hall; SE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 2, T. 11 S., R. 98 W.	Shale. Coal (bottom not exposed).....	 7	10	Prospect 2 miles south of Palisades; sec. 14, T. 11 S., R. 98 W.	Shale, carbonaceous. Coal..... Sandstone.	 7

^a Richardson, G. B., The Book Cliffs coal field between Grand River, Colorado, and Sunnys de, Utah: Bull. U. S. Geol. Survey No. 316, 1907, p. 308.

Sections of coal beds in the Palisades district, Grand Mesa coal field, Colorado—Cont'd.

UPPER COAL (PAONIA SHALE MEMBER, OR FRESH-WATER MESAVERDE)—Cont'd.

No. on Pl. XXI.	Name and location of mine.	Section.	Ft. in.	No. on Pl. XXI.	Name and location of mine.	Section.	Ft. in.
11	Prospect near Pickett ranch; sec. 6, T. 12 S., R. 97 W.	Shale, sandy. Coal..... Sandstone.	6	13	Prospect on Kannah Creek; sec. 26, T. 12 S., R. 97 W.	Shale. Coal..... Sandstone.	7
12	Patterson; sec. 17, T. 12 S., R. 97 W.	Shale, carbonaceous. Coal, bony..... Coal..... Shale.....	1 4 2				
			7				

LOWER COAL (BOWIE SHALE MEMBER, OR MARINE MESAVERDE).

No. on Pl. XXI.	Name and location of mine.	Section.	Ft. in.	No. on Pl. XXI.	Name and location of mine.	Section.	Ft. in.
14	Stokes; NE. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 2, T. 11 S., R. 98 W.	Shale. Coal..... Shale.	3 4	16	Prospect 2 miles south of Palisades; sec. 26, T. 11 S., R. 98 W.	Sandstone. Coal..... Sandstone.	1
15	De Rush; SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 11, T. 11 S., R. 98 W.	Shale. Coal (base not exposed).....	3 4				

ROLLINS DISTRICT.

The Bowie shale member is not represented in the Rollins district or central part of the field. All of the coal is in the Paonia member, which here rests upon the Rollins sandstone. Only one bed of commercial value is known in the western part of the district, but in the eastern part several beds of workable thickness have been opened. The thin beds above the workable coal near Palisades may thicken toward the east, but too little is yet known of them to state whether the beds of coal are continuous for long distances or are more or less lenticular, as they appear to be in the eastern part of the field where they are better exposed.

In the western part of the Rollins district the coal crops out high in the sides of the mesa, the maximum altitude being 8,100 feet. It is exposed in only a few places on account of a surface covering consisting of blocks of basalt derived from the cap rock of the mesa and on account of thickets of cedar, scrub oak, and underbrush that restrain erosion. In the eastern part of the district it crops out lower in the mesa, is better exposed, and has been prospected more extensively. The location of the principal openings is shown on the accompanying map, and the thickness of coal is given in the following table. The mines have all been worked more or less, and a considerable amount of coal is supplied each winter to the local market.

Sections of coal beds in the Rollins district, Grand Mesa coal field, Colorado.

No. on Pl. XXI.	Name and location of mine.	Section.	Ft. in.	No. on Pl. XXI.	Name and location of mine.	Section.	Ft. in.
18	Kuhnley; SE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 34, T. 13 S., R. 95 W.	Shale. Coal, bony in places Coal Shale.	5 6 2 7 6	26	McGruder; sec. 15, T. 13 S., R. 94 W.	Shale. Coal Shale, sandy Coal Sandstone.	3 6 3 3 9 6
19	Rollins; NW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 35, T. 13 S., R. 96 W.	Shale. Coal Shale Coal Shale.	3 2 11 16	27	Ward (Loomis); sec. 12, T. 13 S., R. 94 W.	Shale, carbonaceous Coal Shale, carbonaceous	6 5 4 3 8 10
20	Fairview; sec. 19, T. 13 S., R. 95 W.	Coal Sandstone and shale Shale Coal Coal, bony Sandstone Shale, carbonaceous Coal Shale.	4 60 5 6 6 4 12 5 5 101 6	28	Landerth; SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 8, T. 13 S., R. 93 W.	Sandstone(?). Coal Shale Coal Shale.	5 4 2 6 6 13 10
21	Winton; sec. 16, T. 13 S., R. 95 W.	Shale. Coal Sandstone.	11	29	Degrafenreid; sec. 22, T. 13 S., R. 93 W.	Shale (?). Coal Sandstone.	12
22	Watson; SW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 11, T. 13 S., R. 95 W.	Shale Coal Shale Coal Shale.	2 3 6 8 1 6 7 8	30	Bennett; SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 23, T. 13 S., R. 23 W.	Shale. Coal Shale.	5 6
23	Davis; SE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 11, T. 13 S., R. 95 W.	Sandstone. Coal Bone Coal Shale Coal Sandstone Shale Coal Shale.	3 1 3 1 6 8 1 6 7 25 1	31	Newman; SE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 26, T. 13 S., R. 93 W.	Shale. Coal Shale.	14
24	Blossom; NW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 13, T. 13 S., R. 95 W.	Shale. Coal Shale, carbonaceous Coal Sandstone.	6 1 4 5 6	32	Burdick; sec. 30, T. 13 S., R. 92 W.	Roof not exposed. Coal Coal, bony.	6 2
25	States; NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 13, T. 13 S., R. 95 W.	Shale. Coal Shale Coal Shale.	3 1 7 11	33	Stucker; sec. 27, T. 13 S., R. 92 W.	Shale. Coal, bony in places Shale, carbonaceous Coal Sandstone.	7 3 5 15
				34	Stucker prospect; sec. 21, T. 13 S., R. 92 W.	Shale. Coal Shale Coal Sandstone.	2 6 10 13

The coal is black, subbituminous, with fine texture, dull luster, and conchoidal fracture, and slacks when exposed to the weather. It burns readily, making a good domestic fuel, but shows little tendency to coke. It is usually free from foreign matter, although in some places there is a considerable amount of bone. The coal varies from place to place in purity and in the thickness and number of the beds. At the Kuhnley mine (No. 18) the bed is about one-third bone; at the Rollins mine (No. 19) the same bed contains practically no bone. For several miles east of Surface Creek the beds are thin and few in number and the coal is bony; but still farther east they are more numerous and the coal improves in quality. At the Bennett mine (No. 30) four beds of workable thickness have been prospected, and the Newman mine (No. 31) opened on one of the upper beds has 14 feet of clean coal. Several other mines in the district have equally good coal in beds 7 to 10 feet thick.

The Rollins mine (No. 19) is the only one in the district equipped with steam power, but arrangements have been made for installing machinery at the Fairview mine (No. 20). At the other openings mining is done by hand. The inside haulage is by mules, and the coal is all taken to market in wagons, more or less well graded roads having been constructed to the mines for this purpose.

SOMERSET DISTRICT.

The eastern or Somerset district includes the coal east of Paonia. At its west end the coal crops out in the cliffs about 1,000 feet above North Fork, but at Somerset it is at river level. East of Minnesota Creek it underlies the mesa and crops out again on Coal Creek, which has cut its canyon down to the coal-bearing zone. The beds are extensively exposed farther south, or upstream in the Coal Creek canyon, but were not examined south of the Mosley mine (No. 49).

Coal occurs in both the Paonia and Bowie shale members of the Mesaverde formation in the Somerset district, as shown in the Johnson section (No. 47) of the following table. The upper four beds of this section are in the Paonia member. There are probably other coal beds in this member, but none have been opened and there are few natural exposures, the coal being either burned on the outcrop or covered with brush and surface débris. The Bowie shale contains seven beds of coal that have been prospected, and others of which little is known. The amount of clinker and ash in some places indicates the existence of unknown coal beds of considerable thickness. All the mines and nearly all the prospects of the Somerset district are in the coals of the Bowie shale, or marine Mesaverde.

The coal of the Somerset district is more abundant, better exposed, more easily accessible, and more extensively worked than that of

the other districts. The average thickness of workable coal is probably not less than 65 feet. The productive beds occur at various horizons throughout the Bowie shale, and range in thickness from 4 to 25 feet. The lowest coal is worked at the Conine mine (No. 35), where the bed, 15 feet 8 inches thick, consists of two benches separated by 1 foot 6 inches of shale. The coal of the middle and upper parts of the Bowie shale is worked at the Cooperative mine (No. 36), where the bed is 10 feet 8 inches thick; at the new King mine (No. 38), where it is 12 feet 8 inches thick; and at the Somerset mine, where it is said to be still thicker on account of the coalescence of several beds.

The coal is better in many ways than the fresh-water coal of the Rollins district. It is harder, less liable to slack on exposure to the weather, stands shipment well, and some of it is coking coal. It is black, bituminous, fine grained, with bright vitreous luster and texture ranging from even to seamy, and some of it is conspicuously banded by alternating layers of coal that differ in luster. The coal throughout the district is free from bone or other foreign matter that seriously interferes with mining or marketing.

Sections of coal beds in the Somerset district, Grand Mesa coal field, Colorado.

No. on Pl. XXI.	Name and location of mine.	Section.		No. on Pl. XXI.	Name and location of mine.	Section.	
			<i>Ft. in.</i>				<i>Ft. in.</i>
35	Conine; NW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 24, T. 13 S., R. 92 W.	Shale. Coal..... Shale..... Coal..... Shale.....	 7 8 1 6 6 6 2	39	Prospect on Hubbard Creek; sec. 12, T. 13 S., R. 91 W.	Shale. Coal..... Sandstone.	 12
			17 8				
36	Cooperative; SW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 17, T. 13 S. R. 91 W.	Sandstone. Coal, bony..... Coal..... Shale, carbonaceous.	 2 8 8 6	40	Mallott; sec. 24, T. 13 S., R. 91 W.	Shale, sandy. Coal..... Shale..... Coal..... Shale, sandy.	 4 2 2 12 16 4
			11 2				
37	King (old); NE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 15, T. 13 S., R. 91 W.	Shale. Coal..... Coal, bony..... Sandstone.	 4 4 4 4	41	Whitlaw; sec. 23, T. 13 S., R. 91 W.	Shale. Coal.....	 21
				43	Sylvester; sec. 10, T. 13 S., R. 90 W.	Shale. Coal..... Shale.	 5 10
38	King (new); NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 15, T. 13 S., R. 91 W.	Shale, carbonaceous. Coal..... Shale..... Coal..... Coal ("sulphur streak")..... Coal..... Shale, carbonaceous.	 1 2 3 3 7 4 6 8 8 12 8	45	Hawks Nest; sec. 11, T. 13 S., R. 90 W.	Shale. Coal..... Base not exposed.	 7
				46	Shoecraft (Porter claims); sec. 32, T. 13 S., R. 90 W.	Shale. Coal..... Shale.	 7

Sections of coal beds in the Somerset district, Grand Mesa coal field, Colorado—Cont'd.

No. on Pl. XXI.	Name and location of mine.	Section.	Ft. in.	No. on Pl. XXI.	Name and location of mine.	Section.	Ft. in.
47	Johnson (Porter claims); sec. 5, T. 14 S., R. 90 W.	Paonia member.	Sandstone. Coal..... 12 2 Shale and sand- stone..... 57 Coal..... 3 9 Sandstone and shale..... 40 Coal..... 1 Sandstone and shale..... 40 Coal..... 10 Sandstone..... 85 Coal..... 8 Sandstone..... 50 Ash and clinker .. 20 Coal, metamor- phosed..... 2 Shale and sand- stone..... 48 Coal, metamor- phosed..... 2 Shale and sand- stone..... 40 Coal..... 5 7 Shale..... 25 Coal..... 6 Limestone, shelly. 3 Shale..... 15 Coal..... 5 5 Shale..... 14 Coal..... 6 Shale, sandy..... 21 Coal..... 4 6 Shale, sandy..... 16 Coal..... 3 Shale.	48	Simonton (Porter claims); sec. 22, T. 14 S., R. 90 W.	Shale. Coal..... 2 10 Shale..... 10 Coal..... 1 2 Shale..... 5 Coal..... 13 1 Shale..... 6 Coal..... 16 Coal, bony..... 2 Coal..... 7 2 Shale..... 2 Shale and sandstone. 12 Coal..... 1 Shale.	64 6
		Bowie member.	Coal, metamor- phosed..... 2 Shale and sand- stone..... 48 Coal..... 2 Shale and sand- stone..... 40 Coal..... 5 7 Shale..... 25 Coal..... 6 Limestone, shelly. 3 Shale..... 15 Coal..... 5 5 Shale..... 14 Coal..... 6 Shale, sandy..... 21 Coal..... 4 6 Shale, sandy..... 16 Coal..... 3 Shale.	49	Mosley; sec. 10(?), T. 13 S., R. 89 W.	Shale. Coal..... 2 Shale..... 12 Coal..... 10 Bottom not exposed.	24
			Coal..... 5 5 Shale..... 14 Coal..... 6 Shale, sandy..... 21 Coal..... 4 6 Shale, sandy..... 16 Coal..... 3 Shale.	50	Prospect near Mosley mine; sec. 3, T. 14 S., R. 89 W.	Shale..... 5 Coal..... 8 Sandstone..... 20 Coal..... 1 Shale, sandy.	34
			543 5				

Along the North Fork to the east of Somerset, and on Coal Creek the coal is hard, massive, bituminous to anthracite, and of coking quality, although recent tests in the Denver laboratory of the fuel-testing plant show that the coke is not of the best quality. At the Mosley mine (No. 49) the coal, 10 feet thick, is metamorphosed, probably by the heat from an intrusive igneous rock, although no such rock was found in contact with it. However, it is located in the side of Mount Gunnison, at no great distance from extensive masses of igneous rock. The coal is hard, black, dull vitreous in luster, fine grained, even to seamy in texture, with conchoidal fracture, free from bone, does not slack on exposure to the weather, and cokes readily. A large quantity of equally good coal is reported from Coal Creek, south of the area investigated.

Anthracite coal of good quality occurs in the south slope of Mount Gunnison at an altitude of 9,700 feet. Several exposures were observed, and the beds have been carefully prospected by S. G. Porter. The rocks are faulted, crushed, and cut by dikes of igneous rock to such an extent that individual beds can not be traced for any considerable distance, nor is the coal constant in thickness or character. An opening, known as the Phillip prospect, was started on an 8-foot bed, but the coal is crushed in places, variable in thickness, and at a point 290 feet from the opening pinched out entirely.

The coal is hard and dull in luster, and is virtually a natural coke changed by the heat of igneous rocks, though without vesicular structure, probably because of the pressure of the overlying strata. This coal occurs in comparatively small blocks of the coal-bearing formation, surrounded by and included in the igneous rock of the mountains, and the coal is so disturbed and so uncertain in occurrence that it has not been included within the area here regarded as productive coal land. Although of excellent quality, it is scanty in quantity and difficult of access, and its value from a commercial standpoint is doubtful.

Four mines of the Somerset district were producing at the time of the investigation. Two of these, the Conine and Cooperative, were not equipped with machinery and the mining was done by hand. The King mine (No. 38) was well equipped for mining operations. It is located in the side of the canyon and the coal is lowered 600 feet by means of a gravity incline to the foot of the cliff, where it is screened and loaded directly into cars for shipment. The Utah Fuel Company's mine at Somerset is the largest producer in the district, and is the objective point of the North Fork branch of the Denver and Rio Grande Railroad. No information in regard to this mine could be obtained from the company.

QUANTITY AND VALUE OF COAL.

No close estimate can be made of the amount of coal in this field until more is known of the number of the coal beds and their variations in thickness. The average thickness of workable coal, based on available information, is 11 feet for the Palisades district, 15 feet for the Rollins district, and 65 feet for the Somerset district. It is probable that these figures will be increased when the beds are all prospected. If the practical limit of available coal is assumed to be 6 miles back from the outcrop, there are about 120 square miles of coal land in the Palisades district, about 235 square miles in the Rollins district, and about 195 square miles in the Somerset district. Coal of 1.3 specific gravity weighs 81.25 pounds per cubic foot, and a square mile of coal 1 foot thick contains 1,132,544 short tons. If the estimated thicknesses are correct, the Grand Mesa coal field contains 19,842,270,880 short tons of coal in workable beds. After deducting 25 per cent for waste in mining, there remain 14,881,703,160 short tons of available coal, mainly on Government land.

COMPOSITION OF COAL.

The following analyses show that good coal occurs throughout the field, but that the coal of the Bowie, or marine Mesaverde, is superior to that of the Paonia, or nonmarine beds. In general, Paonia coals have large percentages of moisture and low heating values, are comparatively soft, and slack more or less readily on exposure. The Bowie coals have low percentages of moisture and comparatively high heating values, are relatively hard, and do not slack easily. There is a gradual improvement in quality from west to east, or

toward the mountains, and the coal nearest the intrusive rock at the east end of the field is semianthracite.

The samples for analysis were all taken in the manner described on pages 12-13, and great care was exercised to obtain representative coal.

Analyses of coal samples from the Grand Mesa coal field, Colorado.

[F. M. Stanton, chemist in charge.]

District.....	Gunnison.			Palisades.		Rollins.				
Character of coal.....	Bituminous.			Subbituminous to bituminous.						
Laboratory No.....	5530.	5534.	5724.	5535.	5541.	5542.	5540.	5522.	5539.	5521.
Sample as received:										
Prox. Moisture.....	5.96	6.53	7.18	11.51	17.18	19.14	16.37	14.16	15.26	13.36
Prox. Volatile matter.....	26.41	33.85	32.97	32.60	30.67	31.20	29.79	31.29	30.24	33.72
Prox. Fixed carbon.....	41.21	50.95	50.98	45.53	41.41	41.73	45.39	48.48	45.83	48.69
Prox. Ash.....	26.42	8.67	8.87	10.36	10.74	7.93	8.45	6.07	8.67	4.23
Prox. Sulphur.....	.80	1.11	.58	.93	.70	.75	.45	.68	.60	.56
Ult. Hydrogen.....			5.53			6.06	5.87	5.90	5.87	5.88
Ult. Carbon.....			67.54			55.11	56.74	61.15	59.24	62.11
Ult. Nitrogen.....			1.24			1.10	1.13	1.22	1.11	1.30
Ult. Oxygen.....			16.24			29.05	27.36	24.98	24.51	25.92
Calories.....	4,697	6,078	6,649	5,782	5,202	5,322	5,616	6,016	5,780	6,226
British thermal units.....	8,455	10,940	11,968	10,408	9,364	9,580	10,109	10,829	10,404	11,207
Loss of moisture on air drying.....	2.10	2.10	2.40	2.70	5.00	5.90	4.30	4.90	5.50	4.60
Air-dried sample:										
Prox. Moisture.....	3.94	4.52	4.89	9.05	12.82	14.07	12.61	9.73	10.34	9.18
Prox. Volatile matter.....	26.98	34.58	33.78	33.51	32.28	33.16	31.13	32.90	32.00	35.55
Prox. Fixed carbon.....	42.09	52.04	52.24	46.79	43.59	44.34	47.43	50.99	48.49	51.04
Prox. Ash.....	26.99	8.86	9.09	10.65	11.31	8.43	8.83	6.38	9.17	4.43
Prox. Sulphur.....	.82	1.13	.59	.96	.74	.80	.47	.72	.64	.59
Ult. Hydrogen.....			5.39			5.74	5.63	5.64	5.57	5.63
Ult. Carbon.....			69.20			58.56	59.29	64.30	62.69	65.11
Ult. Nitrogen.....			1.27			1.17	1.18	1.28	1.17	1.36
Ult. Oxygen.....			14.46			25.30	24.60	21.68	20.76	22.88
Calories.....	4,798	6,208	6,813	5,942	5,476	5,656	5,868	6,326	6,116	6,526
British thermal units.....	8,636	11,175	12,262	10,696	9,856	10,181	10,563	11,387	11,010	11,747
Thickness of part of bed sampled.....	<i>Ft. in.</i> 3 4	<i>Ft. in.</i> 1 6	<i>Ft. in.</i> 6 2	<i>Ft. in.</i> 4	<i>Ft. in.</i> 7 6	<i>Ft. in.</i> 11	<i>Ft. in.</i> 6 5	<i>Ft. in.</i> 4	<i>Ft. in.</i> 5	<i>Ft. in.</i> 3 8
District.....	Rollins.							Somerset.		
Character of coal.....	Subbituminous to bituminous.							Bituminous to anthracite.		
Laboratory No.....	5523.	5524.	5538.	5525.	5537.	5536.	5552.	5551.	5526.	5527.
Sample as received:										
Prox. Moisture.....	13.57	9.85	10.24	13.97	15.54	16.67	22.40	8.90	13.64	9.37
Prox. Volatile matter.....	32.58	32.76	31.57	31.90	33.03	33.10	31.19	32.61	30.89	34.75
Prox. Fixed carbon.....	46.17	43.46	42.10	43.23	46.06	46.27	42.16	47.05	47.33	53.04
Prox. Ash.....	7.68	13.93	16.09	10.90	5.37	3.96	4.25	11.44	8.14	2.84
Prox. Sulphur.....	.83	1.83	.60	.54	.58	.47	.30	.81	.68	.50
Ult. Hydrogen.....					5.89			5.34	5.41	5.81
Ult. Carbon.....					60.08			62.03	58.06	69.94
Ult. Nitrogen.....					1.05			1.26	1.24	1.31
Ult. Oxygen.....					27.03			19.12	26.47	19.60
Calories.....	5,921	5,683	5,589	5,667	5,865	5,945	4,533	6,174	5,576	6,883
British thermal units.....	10,658	10,229	10,060	10,201	10,557	10,701	8,159	11,113	10,037	12,389
Loss of moisture on air drying.....	5.40	3.10	3.00	4.70	4.70	5.20	8.80	3.30	5.20	3.60
Air-dried sample:										
Prox. Moisture.....	8.64	6.97	7.46	9.73	11.37	12.10	14.91	5.79	8.90	5.98
Prox. Volatile matter.....	34.44	33.81	32.55	33.47	34.66	34.92	34.20	33.72	32.58	36.05
Prox. Fixed carbon.....	48.80	44.85	43.40	45.36	48.33	48.80	46.23	48.66	49.93	55.02
Prox. Ash.....	8.12	14.37	16.59	11.44	5.64	4.18	4.66	11.83	8.59	2.95
Prox. Sulphur.....	.88	1.89	.62	.57	.61	.50	.33	.84	.72	.52
Ult. Hydrogen.....					5.63			5.14	5.09	5.61
Ult. Carbon.....					63.04			64.15	61.24	72.55
Ult. Nitrogen.....					1.10			1.30	1.31	1.36
Ult. Oxygen.....					23.98			16.74	23.05	17.01
Calories.....	6,259	5,865	5,762	5,946	6,154	6,271	4,970	6,385	5,882	7,140
British thermal units.....	11,266	10,556	10,371	10,704	11,078	11,288	8,946	11,492	10,588	12,850
Thickness of part of bed sampled.....	<i>Ft. in.</i> 6 5	<i>Ft. in.</i> 3 6	<i>Ft. in.</i> 5 4	<i>Ft. in.</i> 5 6	<i>Ft. in.</i> 14	<i>Ft. in.</i> 6 2	<i>Ft. in.</i> 6 6	<i>Ft. in.</i> 7 8	<i>Ft. in.</i> 6 6	<i>Ft. in.</i> 8 8

Analyses of coal samples from the Grand Mesa coal field, Colorado—Continued.

District.....	Somerset.									
Character of coal.....	Bituminous to anthracite.									
Laboratory No.....	5760.	5533.	5531.	5532.	5406.	5405.	5807.	5529.	5344.	5528.
Sample as received:										
Prox. { Moisture.....	3.37	2.41	2.34	2.64	5.49	5.96	21.44	19.23	8.94	4.22
Prox. { Volatile matter.....	35.09	29.14	34.97	28.84	35.65	23.92	29.13	31.04	34.23	3.98
Prox. { Fixed carbon.....	53.02	58.38	58.42	63.31	55.79	66.95	44.75	44.35	52.04	76.02
Ult. { Ash.....	8.52	10.07	4.27	5.21	3.07	3.17	4.68	5.38	4.79	15.78
Ult. { Sulphur.....	.62	.52	.54	.66	.60	.47	.33	.31	.57	.88
Ult. { Hydrogen.....	5.41	4.74	5.37	5.05	5.76	5.68	.....	.....	5.41	.....
Ult. { Carbon.....	71.18	71.93	75.31	76.81	73.22	74.08	.....	.....	68.76	.....
Ult. { Nitrogen.....	1.59	1.18	1.31	1.28	1.22	1.36	.....	.....	1.41	.....
Ult. { Oxygen.....	12.68	11.56	13.20	10.99	16.13	15.24	.....	.....	19.06	.....
Calories.....	7,238	7,020	7,556	7,516	7,343	7,358	4,372	4,871	6,837	6,815
British thermal units.....	13,028	12,636	13,601	13,529	13,217	13,244	7,870	8,768	12,307	12,267
Loss of moisture on air drying.....	.80	1.40	1.10	1.70	2.00	2.70	9.80	10.10	1.70	3.20
Air-dried sample:										
Prox. { Moisture.....	2.59	1.03	1.25	.96	3.56	3.35	12.91	10.16	7.37	1.06
Prox. { Volatile matter.....	35.37	29.55	35.36	29.34	36.38	24.58	32.29	34.53	34.82	4.11
Prox. { Fixed carbon.....	53.45	59.21	59.07	64.40	56.93	68.81	49.61	49.33	52.94	78.53
Ult. { Ash.....	8.59	10.21	4.32	5.30	3.13	3.26	5.19	5.98	4.87	16.30
Ult. { Sulphur.....	.63	.53	.55	.67	.61	.48	.37	.34	.58	.91
Ult. { Hydrogen.....	5.36	4.64	5.31	4.94	5.65	5.53	.....	.....	5.31	.....
Ult. { Carbon.....	71.75	72.95	76.15	78.14	74.72	76.13	.....	.....	69.95	.....
Ult. { Nitrogen.....	1.60	1.20	1.32	1.30	1.25	1.40	.....	.....	1.44	.....
Ult. { Oxygen.....	12.07	10.47	12.35	9.65	14.64	13.20	.....	.....	17.85	.....
Calories.....	7,296	7,120	7,640	7,646	7,493	7,562	4,847	5,418	6,955	7,040
British thermal units.....	13,133	12,815	13,752	13,763	13,487	13,612	8,725	9,753	12,520	12,673
Thickness of part of bed sampled.....	<i>Ft. in.</i> 4 5	<i>Ft. in.</i> 4 9	<i>Ft. in.</i> 6 4	<i>Ft. in.</i> 6 4	<i>Ft. in.</i> 5 10	<i>Ft. in.</i> 5	<i>Ft. in.</i> 7	<i>Ft. in.</i> 7	<i>Ft. in.</i> 7	<i>Ft. in.</i> 5 6

5530.*a* Sec. 26, T. 1 S., R. 1 W. (Ute principal meridian), 80 feet from mouth of opening in deserted mine.5534.*b* Sec. 18, T. 4 S., R. 3 E. (Ute principal meridian), 160 feet from mouth of opening.5724.*c* NW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 34, T. 10 S., R. 98 W., 165 feet from mouth of opening.5535.*a* Sec. 17, T. 12 S., R. 97 W., 125 feet from mouth of opening.5541.*c* SE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 34, T. 13 S., R. 96 W., 2,000 feet from mouth of opening.5542.*c* NW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 35, T. 13 S., R. 96 W., 285 feet from mouth of opening.5540.*c* Sec. 19, T. 13 S., R. 95 W., 800 feet from mouth of opening.5522.*c* Sec. 16, T. 13 S., R. 95 W.; upper bench, 500 feet from mouth of opening.5539.*c* Sec. 16, T. 13 S., R. 95 W.; lower bench, 500 feet from mouth of opening.5521.*c* SW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 11, T. 13 S., R. 95 W., 200 feet from mouth of opening.5523.*c* NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 13, T. 13 S., R. 95 W., 110 feet from mouth of opening.5524.*a* Sec. 15, T. 13 S., R. 94 W., 250 feet from mouth of opening.5538.*a* Sec. 12, T. 13 S., R. 94 W., 200 feet from mouth of opening.5525.*c* SW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 23, T. 13 S., R. 93 W., 50 feet from mouth of opening.5537.*c* SE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 26, T. 13 S., R. 93 W., 240 feet from mouth of opening.5536.*c* Sec. 30, T. 13 S., R. 92 W., 800 feet from mouth of opening.5552.*b* Sec. 21, T. 13 S., R. 92 W.5551.*c* NW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 24, T. 13 S., R. 92 W.; upper bench, 300 feet from mouth of opening.5526.*c* NW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 24, T. 13 S., R. 92 W.; lower bench, 300 feet from mouth of opening.5527.*c* SW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 17, T. 13 S., R. 91 W., 300 feet from mouth of opening.5760.*c* NE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 15, T. 13 S., R. 91 W., 700 feet from mouth of opening.5533.*c* NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 15, T. 13 S., R. 91 W.; upper bench, 700 feet from mouth of opening.5531.*c* NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 15, T. 13 S., R. 91 W.; lower bench, 700 feet from mouth of opening.5532.*c* NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 15, T. 13 S., R. 91 W.; lower bench, 500 feet from mouth of opening. Coal said to be "dead."5406.*a* Sec. 11, T. 13 S., R. 90 W., 70 feet from mouth of opening.5405.*a* Sec. 32, T. 13 S., R. 90 W., 100 feet from mouth of opening.5529.*b* Sec. 22, T. 14 S., R. 90 W.5344.*c* Sec. 10(?), T. 13 S., R. 89 W., 60 feet from mouth of opening.5528.*c* Prospect south of Mount Gunnison.*a* Samples represent coal from freshly cleared sections in abandoned mines.*b* Samples represent weathered coal.*c* Samples represent fresh coal.

THE COAL FIELD BETWEEN GALLINA AND RATON SPRING, NEW MEXICO, IN THE SAN JUAN COAL REGION.

By JAMES H. GARDNER.

INTRODUCTION.

The San Juan coal region (Durango-Gallup coal field)^a is a basin of more or less circular outline, with an area of about 13,500 square miles, about one-seventh of which lies in Colorado and the remainder in New Mexico. The region receives its name from San Juan River. The two chief coal-producing localities are Durango, in the extreme southwestern part of Colorado, on the Denver and Rio Grande Railroad, and Gallup, in New Mexico, on the Atchison, Topeka and Santa Fe Railway. The San Juan coal region is the inner coal-bearing portion of the San Juan Basin.

During the season of 1905 a reconnaissance survey around the east side of this region was made by F. C. Schrader, assisted by M. K. Shaler. Work was begun at Durango, Colo., and carried in an easterly direction to Monero, N. Mex.; thence southward in New Mexico via Elvado, Gallina, and Cuba, to Cabezon; and thence westward to Gallup.

In the season of 1906 M. K. Shaler, assisted by the writer, conducted a reconnaissance survey around the opposite side of the region. Work was tied to that of the previous season at Durango, and the outcrop of the coal formations was mapped around the west side of the region and connected with that of Schrader at Gallup. The coal-bearing formations mapped in each survey are the Mesaverde and Laramie, of Upper Cretaceous age, as classified by Cross^b in the vicinity of Durango.

In the reconnaissance of Schrader in 1905 the outcrops of the Mesaverde and Laramie formations were found to be roughly parallel,

^a Schrader, F. C., The Durango-Gallup coal field of Colorado and New Mexico: Bull. U. S. Geol. Survey No. 285, 1906, pp. 241-258. Shaler, M. K., A reconnaissance survey of the western part of the Durango-Gallup coal field of Colorado and New Mexico: Bull. U. S. Geol. Survey No. 316, 1907, pp. 376-426.

^b Cross, Whitman, La Plata folio (No. 60), Geologic Atlas U. S., U. S. Geol. Survey, 1899.

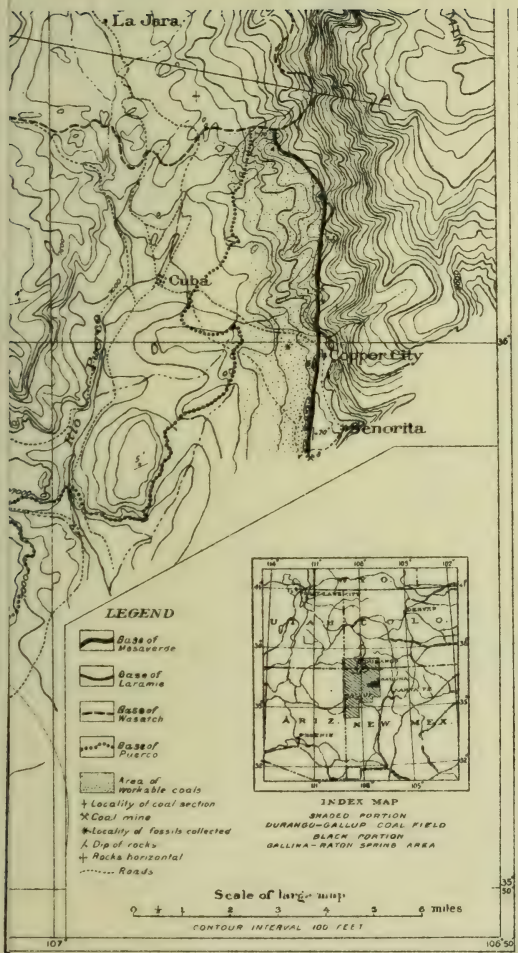
and to be represented by more or less eroded hogbacks, with intervening valleys of softer Lewis shale. This relationship extends from Durango eastward to Monero, and thence southward to the vicinity of Gallina, where the Laramie was found to be no longer marked by a prominent hogback, but to be more or less covered by overlapping Tertiary rocks. This complexity of structure, together with lack of time, compelled the party to discontinue the mapping of the Laramie at this place, and it was not recognized beyond this point. The Mesaverde formation, being more resistant and covered to a less extent by unconformable shale, was easily followed southward.

In Shaler's reconnaissance in 1906 the Mesaverde and Laramie formations were recognized in similar relationship around the west side of the basin to the vicinity of Sulphur Spring, on the drainage of Rio Chaco. Here the Mesaverde and Laramie boundaries were found to diverge, the former continuing southward, the latter bearing off to the east a short distance north of Rio Chaco. The Laramie was traced and mapped as far east as Raton Spring, about 35 miles west of Gallina. At this point the examination of the Laramie was abandoned, but it appeared to continue eastward to the region near Gallina, where Schrader last recognized it a year previous.

The present report covers the area between Gallina and Raton Spring. The field work was carried on from July 20 to August 26, inclusive, 1907, by the writer, assisted by William J. Reed and Albert L. Beekly. To these gentlemen acknowledgments are due for valuable assistance in the field and office. The map (Pl. XXII) presented in connection with this report was prepared by Mr. Reed.

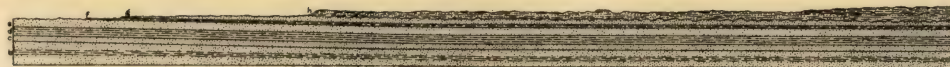
GEOGRAPHY AND TOPOGRAPHY.

Gallina, N. Mex., is a small Mexican settlement of about 100 people, located approximately in latitude $36^{\circ} 15'$ and longitude $106^{\circ} 50'$, at the point where Gallina River emerges from the Sierra Nacimiento. About $14\frac{1}{2}$ miles south-southwest is the old Mexican town of Nacimiento, known to the post-office officials as Cuba. This village contains about 200 inhabitants, and is located in a small fertile valley at the foot of San Pedro Mountain, near the point where Nacimiento Creek joins Rio Puerco. Lajara, Copper City, and Senorito are settlements of less importance. About 34 miles south of west from Cuba is Raton Spring, where there are two Mexican stores and a few dwelling houses. Raton Spring is known also as Pueblo Pintado, a name formerly applied to the Aztec ruins, which are still evident at this place. The spring itself is a deep pool of somewhat alkaline water, which flows as a mere seep. At Ensino Spring, between Cuba and Raton, 11 miles north of east from Raton, there are some Indian stone huts, but the spring is known as a watering place for miles over



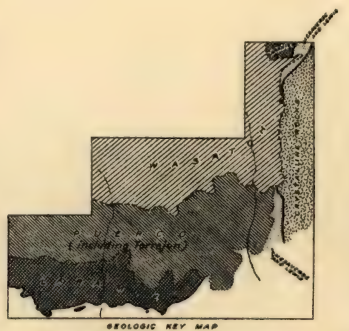


STRUCTURE SECTION ALONG LINE A—A

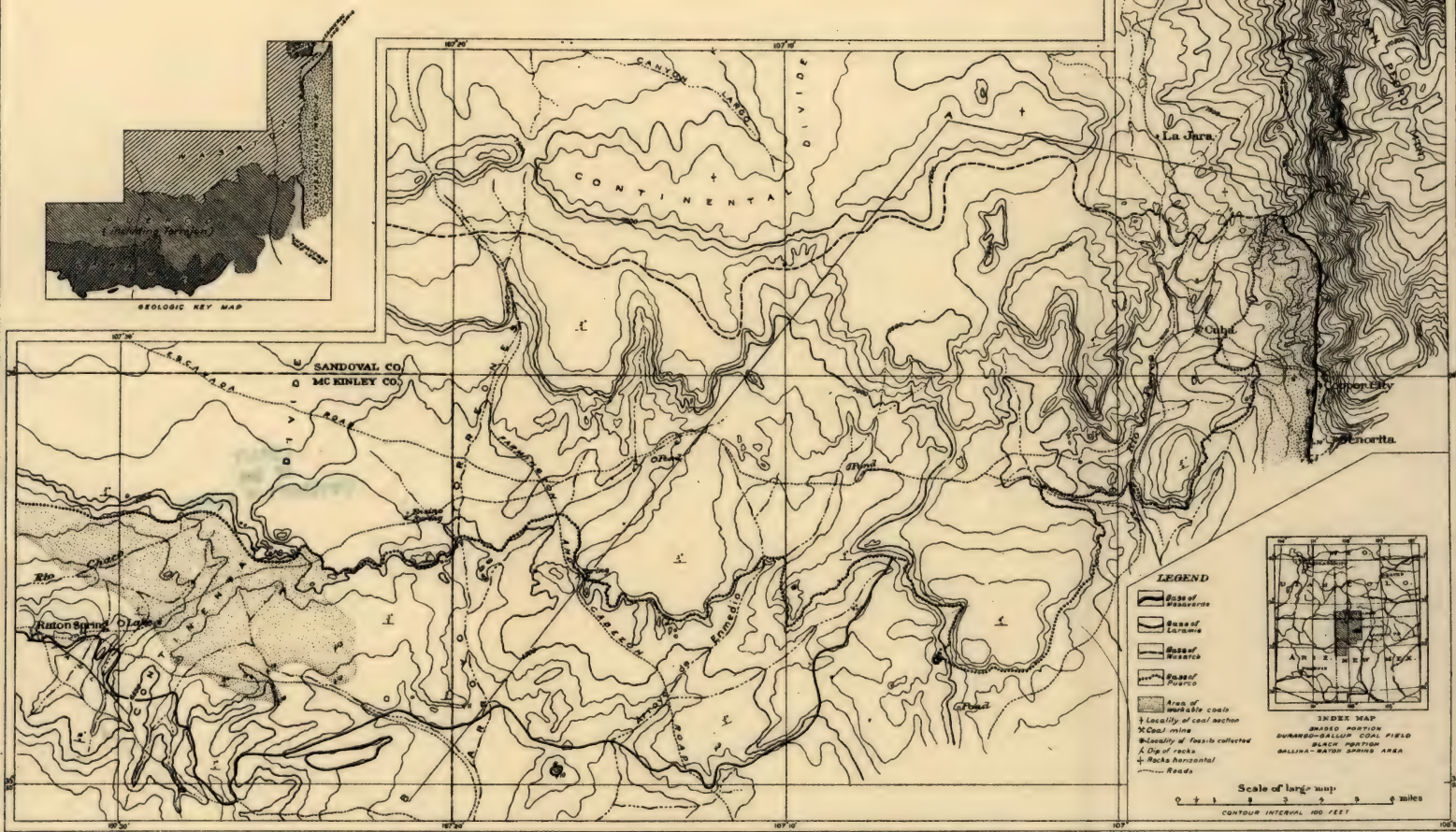


STRUCTURE SECTION ALONG LINE A—B

k, Crystalline rocks; a, Permian?; b, Jurassic-Triassic; c, Dakota; d, Mancos; e, Mesaverde; f, Lewis; g, Laramie; h, Puerco; i, Wasatch; j, Bowldera, Recent.
(including terraces)



GEOLOGIC KEY MAP



MAP OF THE COAL FIELD BETWEEN GALLINA AND RATON SPRING,
NEW MEXICO, IN THE SAN JUAN COAL REGION

By James H. Gardner, William J. Reed, and Albert L. Beekly

the surrounding desert country. The water issues from beneath a massive sandstone, and the flow in August, 1907, was about 1 gallon per minute. These are the only localities worthy of individual mention here, but there are numerous Mexican ranches along the west foot of the Sierra Nacimiento between Gallina and Cuba.

The Sierra Nacimiento is a more or less continuous north-south mountain ridge, with an average elevation of about 9,500 feet, or about 2,500 feet above the surface of the plateau country to the west. Northeast of Cuba the ridge rises to an elevation of 10,162 feet, and is known as San Pedro Mountain. An abundant supply of pure water flows perennially from the slopes of this mountain, the drainage on the north passing down as the source of Gallina River and on the southwest as the source of Rio Puerco. Gallina River flows northward for about 16 miles, then turns eastward to Rio Chama, a tributary of the Rio Grande. Rio Puerco flows southward and is also a tributary of the Rio Grande. On the west the mountain presents a bold front, and along its slopes the sedimentary rocks are steeply inclined and form hogbacks. At some places the slopes are extensively covered by boulders and wash, principally granite and granite porphyry from the mountain mass. In the vicinity of Gallina the Tertiary beds overlap the Cretaceous and lower sedimentary strata, and in places rest against the crystalline rocks of San Pedro Mountain. These Tertiary beds include the Puerco, Torrejon, and Wasatch formations, which cover the broad plateau country, stretching westward to San Juan River. This region is a dry, barren expanse of highly colored mesas and badlands, known as the Nacimiento Desert. The high portion of the plateau along the Continental Divide west of Gallina and east of Canyon Largo is named on the Wheeler map "Los Altos del Utah."^a The country between Cuba and Raton Spring presents a series of Laramie and Tertiary escarpments that have receded to varying distances northward. These escarpments have been dissected into numerous outliers and mesas with gentle, intervening dip slopes in the form of sage-covered plains. Interspersed with these features are numerous canyons and deep arroyos. The principal drainage way of this area is the Arroyo Torrejon. This stream heads along the Atlantic side of the Continental Divide, which crosses the territory in a northeast-southwest direction. In times of heavy rainfall there are numerous small lakes in the area, which are readily soaked up or dry away in the periods of drought that follow. There are no ranches in the area west of Cuba, but only scattered tents of Mexican sheep herders or hogans of a few nonreservation Navajoes.

The area is not subdivided by land lines; however, some surveying is at present being done in the vicinity of Cuba.

^a U. S. Geog. Surveys W. 100th Mer., Atlas sheet No. 69.

GEOLOGY.

STRATIGRAPHY.

GENERAL SECTION.

The formations known to occur within the area included in this report are as follows:

Generalized section of rocks in coal field between Gallina and Raton Spring, N. Mex.

System.	Series or formation.	Thickness in feet.
Quaternary.....	Recent.....	0-50
	Wasatch formation.....	(?)1,000
	Unconformity.....	
Tertiary.....	Torreon formation.....	110
	Unconformity (?).....	
	Puerco formation.....	690
	Unconformity.....	
	Laramie formation.....	900
Cretaceous.....	Lewis shale.....	250-2,000
	Mesaverde formation.....	200-900
	Mancos shale.....	500-1,000
	Dakota sandstone.....	

CRETACEOUS ROCKS.

Dakota sandstone.—The Dakota, or basal formation of the Cretaceous throughout the San Juan region, is exposed in a prominent hogback along the west slope of the Sierra Nacimiento. It consists chiefly of hard quartzite with intercalated shale toward the top, but near the base is made up of reddish sandstone and yellowish shale that grade gradually into the Jurassic-Triassic rocks below. No signs of coal beds were observed in the Dakota, but they are known to occur in other parts of the basin.

Mancos shale.—The Mancos shale rests conformably upon the Dakota. In the type locality at Mancos, Colo., the formation is all shale, but in New Mexico there are transitional sandy beds toward the top. At a point 10 miles north of Gallina a part of the formation becomes arenaceous and forms a hogback in the shale valley. This sandy bed is about 30 feet thick and about 275 feet below the top of the formation. It is no doubt the beginning of the sandstone and shale formation that increases in thickness toward the south and is coal bearing on the south side of the basin.^a The siliceous phase is continuous along the foot of the Sierra Nacimiento, but is prominent only south of Cuba. In the vicinity of San Miguel, 12 miles down Rio Puerco from Cuba, the writer observed a thickness of 300 feet of argillaceous sandstone and sandy shale in the Mancos, grading upward through a transition zone to the Mesaverde.

Mesaverde formation.—The Mesaverde is the most important coal-bearing formation in the area, as well as throughout the San Juan

^a See reports of Schrader and Shaler, already cited.

region. It forms a prominent hogback across the east side of the Gallina-Raton Spring field. The outcrop of the formation enters this field at a point $5\frac{1}{2}$ miles N. 8° E. from Gallina, follows along the foot of the Sierra Nacimiento in a north-south direction, and passes from the area mapped near Copper City. Coal beds occur at varying intervals between a prominent basal and a capping sandstone. The main coal bed of the area is just below the top sandstone.

Lewis shale.—The Lewis is much like the Mancos in appearance. The only point worthy of mention here regarding this formation is its notable change in thickness across the field. From about 2,000 feet north of Gallina it thins to 250 feet on the Arroyo Torrejon and in the vicinity of Raton Spring. It may be, however, that the lower part of the shale in that region is replaced by sandstone which has heretofore been considered Mesaverde.

Laramie formation.—The Laramie is without workable coal beds at the north limit of the field. In fact, Schrader^a maps the entire area northward to the Colorado State line as barren. West of Gallina the Laramie and underlying Lewis shale disappear beneath unconformable Eocene beds. The next point to the south at which the Laramie shows is where it emerges from beneath the Puerco, about $10\frac{1}{2}$ miles southwest of Cuba. The Laramie strata exposed between this point and Raton Spring are coal bearing, the coal beds increasing in thickness and number toward the west.

TERTIARY ROCKS.

In the vicinity of Gallina and to the south beyond Lajara the variegated shales of the Wasatch rest horizontally against the foot of the Sierra Nacimiento, covering the highly inclined strata of the Cretaceous and lower sedimentary rocks. The Wasatch bears many fragments of vertebrates, and collections were sufficient to permit its positive identification.

In the southern portion of the area, along the mountain foot northeast of Cuba and along the headwaters of Rio Puerco, the Wasatch is underlain by a mass of variegated and bituminous shale, with two beds of massive sandstone. The sandstones form prominent escarpments, the upper immediately west and the lower about 10 miles southwest of Cuba. The entire thickness of these beds is about 800 feet. They are highly inclined along the mountains, and northeast of Cuba they are overturned and dip toward the mountains at about 70° . The high dips of the massive sandstones are in marked contrast to the unconformable horizontal shale of the overlying Wasatch. The prominent sandstone escarpments swing westward from Cuba, the lower being traced across the area beyond the limits of the present

^a Op. cit., p. 243.

mapping. The upper escarpment could not be traced with certainty. The prominent escarpment of the Wasatch to the north follows in a general way parallel to these escarpments. Near a small pond, about 7 miles N. 76° E. of Ensino Spring, vertebrate fossils were collected from 25 feet of dark and gray argillaceous sand and shale immediately overlying the basal escarpment sandstone. A careful study of these fossils has been made by J. W. Gidley, of the United States National Museum, and the specimens have been compared with original material in the American Museum of Natural History, New York. This comparison definitely places them in the Torrejon formation.^a The Laramie reappears from beneath the lower escarpment, striking almost at right angles with it, thus bringing out a marked unconformity between the two. It does not follow from the fossils that the lower escarpment is of Torrejon age. It is probable that there is an unconformity between the Puerco and the Torrejon. This accounts for the Torrejon fossils immediately above the basal escarpment sandstone, which is in all probability the lowest member of the Puerco. It is certainly at the base of an 800-foot mass below the Wasatch, exposed along the headwaters of Rio Puerco, as originally described by Cope.^b Along Rio Puerco the base of the Wasatch is 750 feet above the top of the basal Puerco sandstone. At the point where the Torrejon fossils were collected the base of the Wasatch, as determined by both stratigraphic relationship and fossil evidence, is only 135 feet above the top of the same sandstone. Hence the 800 feet of the original Puerco is represented by only the basal sandstone, from 30 to 50 feet thick, unconformably overlying the Laramie. This sandstone is unconformably overlain by 110 feet of Torrejon, above which, also unconformably, lies the Wasatch. Space does not permit a detailed discussion of the Tertiary rocks in this preliminary report, but such a discussion will appear as a chapter in the report on the entire field, to be published as a separate bulletin of the Survey.

QUATERNARY DEPOSITS.

The local terrace deposits, granite wash, etc., occurring between Gallina and Cuba and resting in places upon the Wasatch beds, also the alluvium and adobe clays along the present drainage ways, used as building materials by the natives, are classed as Quaternary.

STRUCTURE.

Mention has been made of the hogbacks composed of steeply dipping strata along the crystalline rocks of the Sierra Nacimiento. The Cretaceous rocks in the vicinity of Gallina dip to the west at an angle of 60°; farther south the dips are steeper, reaching 90° near

^a Torrejon is a name proposed by J. L. Wortman (Bull. Am. Mus. Nat. Hist., vol. 9, 1897, pp. 260-261) for a fossil zone at the top of the original Puerco of Cope.

^b Cope, E. D., Rept. Chief Eng., 1875, pt. 2, p. 1008.

Lajara; and along the foot of San Pedro Mountain east of Cuba the rocks are overturned and dip 70° E. The highly tilted Puerco and Torrejon indicate an elevation of the Sierra Nacimiento after their deposition. This elevation took place at the close of Torrejon time, as shown by the fact that the superjacent Wasatch beds lie apparently level against the mountain.

There are two prominent unconformities by overlap in the beds above the Laramie—one at the base of the Puerco, the other at the base of the Wasatch. The relation of these unconformities, dips, etc., may be obtained from the accompanying map (Pl. XXII). In the vicinity of Ensino Spring and of the lake 7 miles north of east from the spring there are local domes in the strata. Such local changes in dips prevent an accurate estimate of thickness by topographic lines on the map. As discussed under the heading "Tertiary rocks," there is also very strong evidence of an unconformity between the Puerco and the overlying Torrejon.

There are few faults aside from local displacements along the east side of the field adjacent to the mountains. Many such minor dislocations occur along the strike of the sedimentary beds where they rest in close proximity to the crystalline rocks, but they are not of sufficient importance for discussion here. The only fault deserving mention is the one at Raton Spring. This is a tension fault with a stratigraphic throw of 60 feet. The strike is inconstant, but averages about S. 50° E. from the spring for a distance of several miles, the downthrow being on the northeast side. The spring issues near the fault and doubtless has its source along the fault plane.

THE COAL.

COAL-BEARING FORMATIONS.

The two coal-bearing formations are the Mesaverde and the Laramie. Coal has been mined in this field from the former only, and that to a very slight extent in one locality. One mile southwest of Senorito the upper bed of the Mesaverde has been opened and mined for local use by the Juratrias and other copper companies, which have now discontinued operations. The coal was used for steaming and smelting as well as for domestic purposes, and is reported to have given general satisfaction.

The Laramie is covered by the overlap of the Tertiary in the vicinity of Gallina, on the north side of the field. At this point it is barren of workable coal beds. Its boundary beneath the Tertiary diverges from that of the north-south line of the Mesaverde, and at its reappearance on the south side of the field is about 12 miles west of the Mesaverde boundary. From this point the strike turns westward and the formations begin to show thin coal beds which increase in thickness and number toward Raton Spring.

DETAILED DESCRIPTION.

The coals of the area are here described by two districts. One is along the exposure of the Mesaverde in a north-south direction across the east side of the field, and is designated the Gallina-Cuba district. The other includes the Laramie area in the vicinity of Raton Spring, and is termed the Raton Spring district.

GALLINA-CUBA DISTRICT.

Locality No. 1:^a The following is a general section of the Mesaverde formation at locality No. 1, 5½ miles N. 8° E. of Gallina, where the rocks dip N. 75° W. at an angle of 36°.

Section of Mesaverde formation 5½ miles N. 8° E. of Gallina (No. 1).

	Ft.	in.
Sandstone, brownish, massive, coarse grained.....	35	
Shale.....	20	
Coal.....		7
Shale.....	8	
Sandstone.....	8	
Coal.....	2	
Sandstone.....	8	
Shale.....	5	
Coal.....		1
Shale.....	12	
Sandstone.....	4	
Coal.....	1	1
Shale.....	8	
Sandstone, carbonaceous.....		1
Coal, resinous.....	1	2
Sandstone and shale.....	2	
Sandstone, carbonaceous.....	1	
Shale.....	2	
Coal.....		4
Shale.....	3	
Sandstone and shale.....	3	
Coal.....		2
Shale.....	5	
Sandstone.....	21	
Coal.....		4
Shale, brown, lignitic.....		3
Coal.....	1	4
Shale.....	13	
Coal.....	1	
Shale, brown, lignitic.....	5	
Coal.....		1
Shale, brown, lignitic.....	1	3
Coal.....		11
Shale, brown, lignitic.....		4
Coal.....	1	10
Shale, brown, lignitic.....	1	4
Coal.....		2

^a These numbers correspond to numbers on the map. Pl. XXII.

	Ft.	in.
Shale with selenite.....	1	8
Shale and thin beds of sandstone, good roof.....	4	
Coal.....	3	
Sandstone.....	1	
Shale, grayish.....	1	
Sandstone, carbonaceous.....		2
Sandstone, brown, massive.....	35	
	214	

It will be observed that in this section there are fourteen coal beds that are not of workable thickness, and only one—the 3-foot bed just above the basal sandstone—that is more than 2 feet thick. The coal of this bed is apparently a good grade of subbituminous ^a coal.

Locality No. 2: About 2½ miles northwest of Gallina the Mesaverde formation shows two workable beds which are probably identical with some of the thin beds farther north. The lowest coal horizon is covered in this vicinity. The following is a section of these beds; the strata dip 45° N. 45° W.

Section of Mesaverde coal-bearing rocks 2½ miles northwest of Gallina (No. 2).

	Ft.	in.
Sandstone, massive.....	50	
Sandstone, shale, and thin coal beds.....	100	
Shale.....	10	
Coal.....	3	2
Shale.....	3	
Sandstone and shale.....	50	
Shale.....	20	
Coal.....	2	8
Shale.....	10	
Shale, sandstone, and traces of coal.....	120	
Sandstone, massive.....	50	
	418	10

Locality No. 3: South of Gallina no workable coals were observed in the Mesaverde, although the bed occurring elsewhere immediately above the basal sandstone may be present here. This coal bed is associated with over 100 feet of thin sandstone and shale, and along the steep hogback a valley is formed at this horizon; as a result the talus from the protruding basal sandstone, together with dwarf vegetation, completely covers the beds in this vicinity. The two workable beds that are present at locality No. 2, northwest of Gallina, have probably thinned very much or disappeared.

Inasmuch as there are several thin beds in the upper portion which on the surface show a considerable quantity of loose coal, it seems well to give a general section of the Mesaverde coal beds in this locality.

^aThe term subbituminous has been adopted by the Geological Survey for that class of coal commonly known as "black lignite."

The higher beds are covered by unconformable Tertiary shale. The following is a section at this place, where the strata dip 60° W.:

Section of Mesaverde formation 3½ miles S. 65° W. of Gallina (No. 3).

	Ft.	in.
Sandstone.....	2	
Shale, brown.....	10	
Coal.....	1	4
Shale, brown.....	15	
Shale, gray.....	3	
Shale, drab.....	50	
Coal.....	1	3
Shale, brown.....	3	
Coal, bony.....		4
Shale, gray.....	2	6
Coal.....	1	
Shale.....	16	
Sandstone and shale.....	8	
Coal, bony.....		4
Shale.....	12	
Coal, bony.....		6
Shale.....	12	
Sandstone.....	2	
Covered; probably contains coal bed.....	120	
Sandstone, basal, massive.....	55	
	315	3

Locality No. 4: At a point S. 50° W. of Gallina the Mesaverde disappears beneath unconformable Tertiary and granite wash. Between this point and the hogback, 3½ miles N. 40° E. of Cuba, the formation is covered except for a small outcrop of resistant sandstone here and there. Where the hogback reappears northeast of Cuba the formations from Triassic up to Puerco, inclusive, are overturned and dip 70° E. At this point the following section was taken in the Mesaverde:

Section of Mesaverde formation 3½ miles N. 40° E. of Cuba (No. 4).

	Ft.	in.
Sandstone, gray.....	25	
Coal.....		6
Shale, carbonaceous.....	3	
Coal, bony.....		7
Shale, drab, hard.....	1	7
Coal.....	4	3
Shale, carbonaceous.....	10	
Sandstone.....	2	
Shale, carbonaceous.....	15	
Covered by granite wash.....		
	61	11

The coal bed in this section is apparently made up of excellent coal, so far as physical appearances show. This is the bed which has been locally mined at Seniorito, 6 miles farther south.

Locality No. 5: The following is a section of the Mesaverde rocks at a prominent cirque 1 mile north of Copper City. The local dip here is 60° S. 30° E.

Section of Mesaverde formation 1 mile north of Copper City (No. 5).

	Ft.	in.
Sandstone, top escarpment.....	45	
Covered; signs of coal.....	10	
Shale, dark; some sandstone and thin coal streaks.....	110	
Coal.....	1	
Shale.....	12	
Coal.....	1	
Shale, drab, and thin sandstone.....	200	
Coal.....		6
Shale, carbonaceous.....	3	
Coal.....	2	2
Shale, drab.....		6
Coal.....		3
Shale.....		6
Coal.....	1	10
Shale.....		6
Coal.....	1	6
Shale, carbonaceous.....	1	
Shale, drab.....	5	
Sandstone, gray.....	4	
Shale, carbonaceous.....	4	
Coal.....	1	
Shale, carbonaceous.....	5	
Coal.....	2	
Shale, carbonaceous.....	1	
Shales, dark and drab.....	30	
Shale, carbonaceous, and thin sandstone.....	20	
Sandstone, massive, gray, resistant.....	30	
Covered; largely shale.....	40	
Sandstone, gray, soft.....	40	
Shales, drab and yellowish.....	15	
Sandstone, gray, soft, massive.....	100	
Sandstone, fossiliferous.....	1	6
Sandstone, thin bedded.....	5	
Shale, drab.....	3	
Sandstone, gray, soft, argillaceous.....	20	
Sandstone, brown, ferruginous.....	2	
Shale, Mancos.....		
	719	3

Locality No. 6: Another exposure of Mesaverde coal beds occurs in the hogback at Copper City. The rocks are overturned, dipping at an angle of 70° S. 70° E., toward San Pedro Mountain. A massive resistant sandstone 50 feet thick caps the formation, and a similar one lies at the base. Between the two is a series of alternating thin sandstones and shales with small intercalated coal beds. These

coal beds are scarcely more than traces with the exception of the bed stratigraphically near the top, which shows a thickness of $5\frac{1}{2}$ feet of clear coal. This bed occurs also at locality No. 4, and carries good coal in the vicinity of Senorito. The following is a detailed section of Mesaverde at this locality:

Section of Mesaverde formation at Copper City (No. 6).

	Ft.	in.
Sandstone, massive.....	50	
Sandstone, thin-bedded.....	5	
Shale, carbonaceous.....	2	
Coal.....	5	6
Shale, brown.....	2	
Coal.....	1	
Shale and thin sandstone.....	32	
Shale, brown, carbonaceous.....	6	
Coal.....		2
Sandstone, grayish, soft.....	12	
Coal.....		6
Shales, drab and brown.....	13	
Coal.....		4
Sandstones, with drab and brown shales.....	50	
Shale, brown, carbonaceous		6
Coal.....		2
Shales, drab and dark, with thin sandstones.....	80	
Coal.....		4
Sandstone, thin, and shale.....	10	
Coal.....		4
Shale, brown.....	4	
Coal.....	1	
Shale, dark.....	10	
Coal.....		4
Shale, dark.....	5	
Coal.....		3
Shale, brown.....	1	
Coal.....		9
Sandstone, thin, and shale.....	12	
Coal.....		6
Shale, carbonaceous.....	8	
Sandstone, massive, basal.....	50	
	363	8

Locality No. 7: At locality No. 7, three-fourths of a mile west of Senorito, the Senorito bed is exposed, dipping 70° E., showing the following section:

Section of Senorito coal bed three-fourths of a mile west of Senorito (No. 7).

	Ft.	in.
Sandstone, massive; top of Mesaverde.....	50	
Shale, brown, carbonaceous, slickensided.....	4	
Coal, clear.....	4	6
Shale, brown, carbonaceous.....	10	
Covered.....		
	68	6

Locality No. 8: One mile southwest of Senorito, near the Cuba-San Miguel road, the top coal bed of the Mesaverde has been mined to some extent for local purposes. At this locality the strata are overturned, as at points farther north, the rocks dipping east at an angle of 70° . Mining is reported to have been done by the Juratrias and other copper companies formerly operating local smelters at Copper City. The chief developments at the coal mine are a well-timbered 20-foot shaft following the dip of the coal and a small head frame with a windlass hoist. In the overturned rocks the brown arenaceous shale stratigraphically overlying the coal becomes the floor; the brown shale below becomes the roof. The bed at this point is 6 feet thick and is composed of clear coal. The coal has a black, shiny luster and is apparently a high-grade subbituminous coal, but unfortunately a good sample for analysis could not be obtained from the partly filled shaft. The coal is reported on good authority to have given general satisfaction as a steam and domestic fuel.

From this locality to the limit of the field here described the Mesaverde formation is steeply inclined eastward toward the Sierra Nacimiento. Farther south the beds assume a normal attitude, dipping steeply westward toward the interior of the basin.

RATON SPRING DISTRICT.

The Laramie emerges from beneath the Puerco $12\frac{1}{2}$ miles S. 70° W. from Senorito, and then turns westward toward Raton Spring. This formation is apparently without workable coal beds in this vicinity, but thin beds make their appearance within a short distance and become more prominent to the west. The formation dips slightly northward and does not stand in bold escarpments. Coal exposures are few and occur in small outliers irregularly over the district. Near Raton Spring there are three beds, two averaging 3 feet and the other 2 feet in thickness. Locally they show thicknesses of $3\frac{1}{2}$ or 4 feet.

Locality No. 9: The first coal exposure noted west of the point of emergence is 1 mile east of the Farmington and Cabezon road. Here the following section was taken, the rocks dipping 3° N.:

Section of Laramie coal beds 1 mile east of Farmington-Cabezon road (No. 9).

	Ft. in.	
Sandstone, brown, hard.....	2	
Shale, very compact, sandy.....	20	
Coal.....	1	1
Coal, bony.....		5
Coal.....		5
Shale, carbonaceous.....		6
Shale, brown.....	1	6
Shale, gray, sandy.....	20	
Covered.....		
	45	11

This bed is near the top of the basal Laramie sandstone, which at this place is largely covered.

Locality No. 10: The next indication of coal is $4\frac{1}{2}$ miles S. 80° W. from locality No. 9. Here the following section was taken of a small outlier at the base of the Laramie:

Section at base of Laramie, locality No. 10.

	Ft.	in.
Sandstone, brown, massive.....	15	
Coal.....		6
Shale, gray, sandy.....	90	
	105	6

At this horizon farther west a workable bed makes its appearance.

Locality No. 11: At locality No. 11, $3\frac{1}{4}$ miles N. 53° W. of locality No. 10, the following section was obtained on Arroyo Torrejon at practically the same horizon. The rocks here dip N. 5° W.

Section of Laramie coal beds at locality No. 11.

	Ft.	in.
Sandstone, brown, massive.....	20	
Sandstone, carbonaceous.....		8
Coal.....		3
Sandstone.....	1	
Coal.....		2
Sandstone, gray.....	35	
Sandstone, carbonaceous.....	3	
Shale, drab.....	4	
Coal.....		8
Shale.....	5	
Sandstone, soft, grayish.....	40	
	109	9

It will be noted that the coal beds of this section are too thin to work, but the section is given in order to indicate the gradual increase westward in the thickness and number of the coal beds.

Locality No. 12: The next locality of coal exposure is $3\frac{1}{2}$ miles N. 80° W. of locality No. 11, and at this point the first section of clear coal of workable thickness was obtained. This is the lowest workable bed of the area, and is designated coal bed A. The rocks here dip 3° N.

Section of coal bed A at locality No. 12.

	Ft.	in.
Covered; mostly shale.....	30	
Shale, black, carbonaceous.....	4	
Shale, brown.....	5	
Shale, drab.....	10	
Sandstone, grayish.....	4	
Coal A.....	2	6
Shale, carbonaceous.....	10	
Sandstone, grayish.....	20	
	85	6

The coal of this section has a very black, glossy luster, and apparently does not alter rapidly on exposure.

Locality No. 13: At locality No. 13, 1 mile north of No. 12, the following section was obtained. The bed in this section is designated B, being next above coal bed A of locality No. 12:

Section of coal bed B at locality No. 13.

	Ft.	in.
Sandstone, gray, thin bedded.....	3	
Shale, drab.....	6	
Shale, brown.....	1	
Bed B {	Coal.....	1
	Shale, carbonaceous.....	1
	Coal.....	10
Covered.....		
	12	10

Locality No. 14: At locality No. 14, 3 miles N. 30° W. from No. 13, a coal bed 2 feet thick is exposed about 20 feet stratigraphically above bed B. This bed is designated C. A section taken at a small outlier shows the following relations:

Section of coal bed C at locality No. 14.

	Ft.	in.
Sandstones, thin, and shale.....	6	
Shale, carbonaceous.....	1	
Coal bed C.....	2	2
Shale, carbonaceous.....	3	
Covered.....		
	12	2

Locality No. 15: At locality No. 15, about 2¼ miles S. 5° W. from No. 14, there is a northward-facing escarpment which shows complete sections of beds A and B, together with part of bed C. The coal-bearing section is as follows:

Section of Laramie coal beds at locality No. 15.

	Ft.	in.
Shale and coal, bed C.....		
Covered.....	20	
Bed B {	Coal.....	1 8
	Shale, sandy.....	1
	Coal.....	10
	Shale, sandy.....	1
	Coal.....	1 6
Shale, carbonaceous.....	2	
Shale, gray, sandy.....	15	
Sandstone, grayish, brown.....	3	
Shale, drab.....	15	
Coal streak.....		
Shale, carbonaceous.....	3	
Bed A {	Coal.....	1
	Shale, sandy.....	2
	Coal.....	2
Shale.....	3	
Covered.....		
	68	4

Locality No. 16: At locality No. 16, 1 mile S. 20° E. from No. 15, the following section was taken immediately above the basal sandstone, showing coal bed A and small related beds:

Section of Laramie coal-bearing rocks at locality No. 16.

	Ft.	in.
Sandstone, gray, massive.....	15	
Shale, carbonaceous.....	18	
Coal.....		4
Shale, carbonaceous.....	1	8
Coal.....		6
Shale.....		8
Coal.....		4
Shale, drab.....	3	
Coal, bed A.....	2	6
Shale, carbonaceous.....	10	
Sandstone, gray, soft.....	20	
Covered.....		
	72	

Locality No. 17: One mile N. 52° W. from locality No. 16, bed A shows a thickness of 4 feet 7 inches, with a sandy shale parting toward the top varying from 1 to 2 inches. The following is the section at this place:

Section of coal bed A at locality No. 17.

	Ft.	in.
Covered.....		
Shale, sandy.....		7
Coal.....	1	5
Shale, sandy.....		$\frac{1}{2}$
Coal.....	3	2
Shale, dark.....	3	
Covered.....		
	8	2 $\frac{1}{2}$

Locality No. 18: At locality No. 18, about $3\frac{1}{4}$ miles north of east of Raton Spring, beds B and C are exposed. These beds are much burned in the vicinity, and the red baked shale stands out in marked contrast to the surrounding rocks, affording a reliable guide in tracing the coal beds. A section was measured at the head of an arroyo, where erosion has removed the greater part of the burned material. The relations at this point are as follows:

Section of Laramie rocks at locality No. 18.

	Ft.	in.
Sandstone, gray.....	3	
Coal, bed C.....	2	
Shale, carbonaceous.....	3	
Shales, drab.....	25	
Shale, carbonaceous.....	1	
Bed B {	Coal.....	6
	Shale.....	3
	Coal.....	3 7
Shale, dark.....	3	
Covered.....		
	41	4

Westward from this locality the coal boundaries were traced beyond the limit of the area mapped, but no sections were obtained. The beds are much burned and covered along the head drainage of Rio Chaco north of Raton Spring. In the immediate vicinity of Raton the geologic mapping connects with that of Shaler^a in 1906.

DEVELOPMENT AND TRANSPORTATION.

The only coal mining in the Gallina-Raton Spring field has been done in connection with the operations of local copper companies at Copper City, in the Gallina-Cuba area. A mine was worked here for a brief time on the upper coal bed of the Mesaverde, but was discontinued with the closing of the smelters. The coal gave good satisfaction and is evidently a high-grade coal of the subbituminous class. The coals in the Raton Spring area have not been prospected and little can be said regarding their quality. They resist weathering fairly well, however, and from all appearances are similar to the best Laramie beds throughout the San Juan region. The topography of the region is such that practicable railroad routes may be found to any part of the field. The nearest railroad points at present are on the Denver and Rio Grande, 45 miles north of Gallina; the Farmington branch of the same line, 55 miles N. 35° W. from Raton Spring; and the Atchison, Topeka and Santa Fe, 48 miles S. 35° W. from Raton Spring.

^a Op. cit.

THE COAL FIELD BETWEEN DURANGO, COLORADO, AND MONERO, NEW MEXICO.

By JAMES H. GARDNER.

INTRODUCTION.

In 1905 a reconnaissance survey of the area between Durango, Colo., and Monero, N. Mex., was conducted by F. C. Schrader,^a assisted by M. K. Shaler. The work of that season was carried on too rapidly to permit the location of coal boundaries with reference to land lines, the chief object being a hasty determination of the extent and value of the entire San Juan coal region (Durango-Gallup field).^b Since that time the outcrops of the coal beds from Durango to Rio Florida have been carefully surveyed by Joseph A. Taff.^c

During the season of 1907 the writer, assisted by William J. Reed and Albert L. Beekly, conducted a resurvey of the field eastward from Durango to Monero, N. Mex. It seems desirable to publish a brief review of this area in connection with a map (Pl. XXIII) showing more accurately the boundaries of the coal-bearing formations.

GEOLOGY.

STRATIGRAPHY.

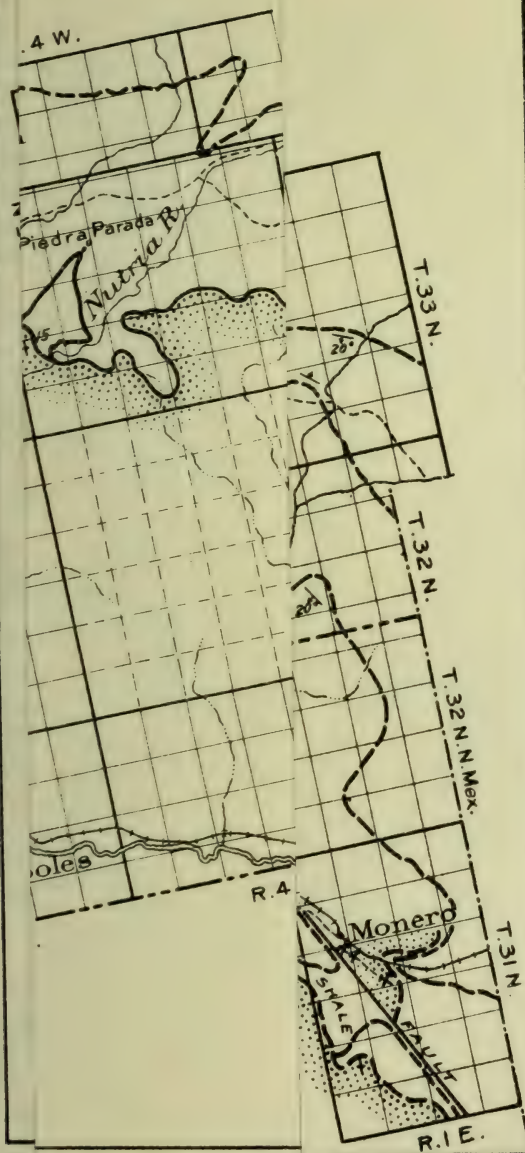
The Cretaceous formations in this area, from the base upward, are as follows: Dakota sandstone, 300 (?) feet; Mancos shale, 1,200 feet; Mesaverde formation, 1,000 feet; Lewis shale, 1,600 feet; and Laramie formation, 700 feet. Of these the Dakota, Mesaverde, and Laramie contain workable coal beds in certain regions. In the area considered, however, the Dakota coal is not known to be of commercial value.

The Mesaverde is the most important of the coal-bearing formations in the Durango district, containing three or four workable beds of excellent bituminous coal, some beds locally being suitable for the

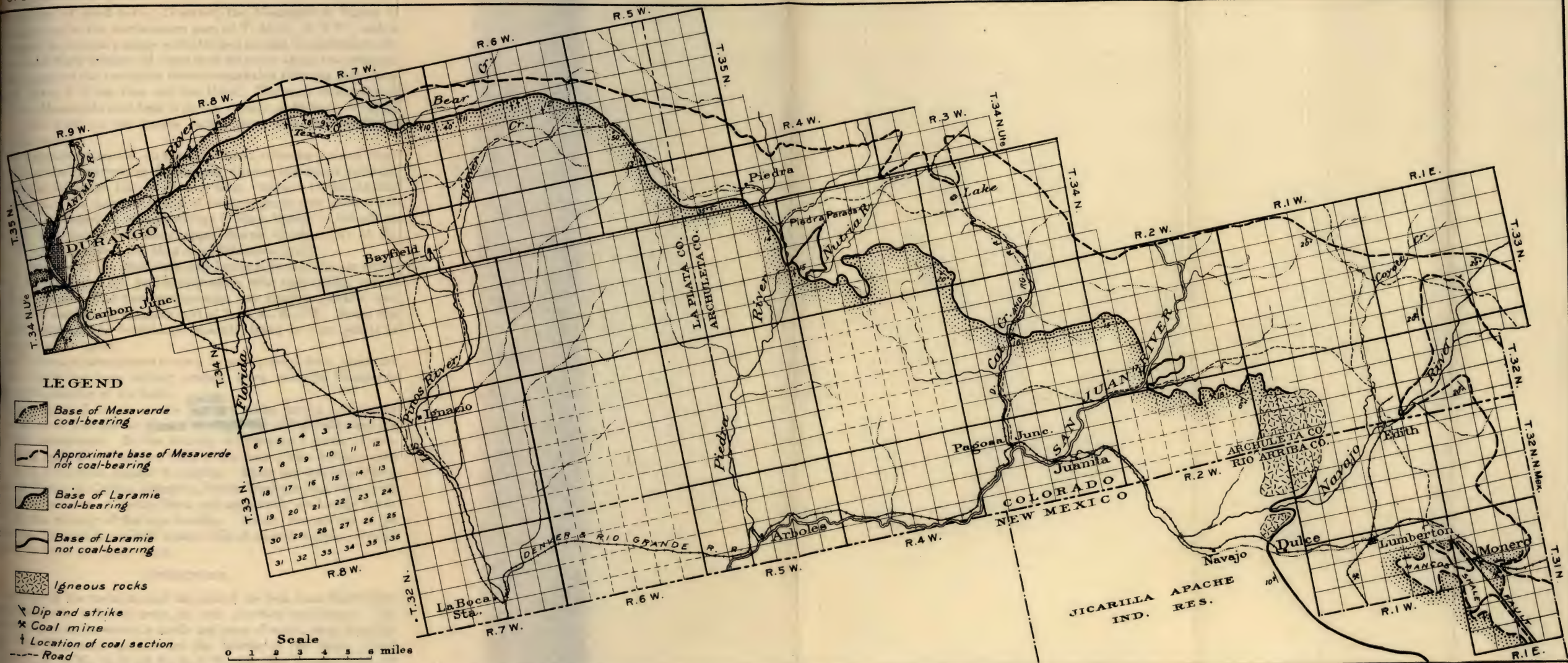
^a The Durango-Gallup coal field of Colorado and New Mexico: Bull. U. S. Geol. Survey No. 285, 1906, pp. 241-258.

^b For a description of the west side of the field, see Shaler, M. K., A reconnaissance survey of the western part of the Durango-Gallup coal field: Bull. U. S. Geol. Survey No. 316, 1907, pp. 376-426.

^c The Durango coal district, Colorado: Bull. U. S. Geol. Survey No. 316, 1907, pp. 321-337.



COLORADO, AND MON
Reed, and Albert L. Beek



MAP OF THE COAL FIELD BETWEEN DURANGO, COLORADO, AND MONERO, NEW MEXICO

By James H. Gardner, William J. Reed, and Albert L. Beekly

manufacture of good coke. However, the Mesaverde is barren of workable coal in the northeastern part of T. 35 N., R. 8 W., and is not known to contain a single workable bed around the northeast side of the basin for a distance of more than 60 miles along the outcrop. In this distance the formation shows remarkable thinning, and along Piedra River it is less than 400 feet thick. The next occurrence of workable Mesaverde coal beds is in the vicinity of Monero, N. Mex., and to the south on the Apache Indian reservation and the Tierra Amarilla grant.

The Laramie formation, on the other hand, contains coals of lesser value than the Mesaverde in the Durango district, and shows workable beds along its entire line of outcrop from Durango to the Apache reservation. The Laramie coal is of medium grade over most of the area, and is classed as subbituminous ("black lignite"), though an analysis of Laramie coal along upper Beaver Creek, in T. 35 N., R. 6 W., closely approaches that of a bituminous coal.

The outcrops of the Mesaverde and Laramie formations are represented by hogbacks and bold escarpments, with intervening valleys of Lewis shale. The two escarpments are roughly parallel and extend eastward to the southern part of T. 35 N., R. 5 W. From this vicinity eastward the boundaries separate, being at some points as much as 8 miles apart.

The Dakota at most places forms a broad dip slope, from which the Mancos shale has been entirely eroded, along with the Mesaverde toward the interior of the basin.

Overlying the Laramie are the Tertiary rocks, having a thickness of about 2,500 feet and at places forming a line of high hills near the Laramie escarpment. In the vicinity of Durango a series of conglomerate beds about 300 feet thick at the base of the Tertiary were named by Cross^a the Animas formation. These are well exposed on Animas River at Carbon Junction, below Durango, but they were not recognized east of Piedra River and apparently are locally developed in the vicinity of the type locality. Toward the interior of the basin the Tertiary forms high broken hills of smooth outline, covered largely by pine and piñon trees.

STRUCTURE.

The dips of the rocks around this side of the San Juan Basin differ considerably in different areas, in both direction and degree. The general direction, however, is south and west of south, away from the San Juan Mountains and toward the interior of the basin. From T. 35 N., R. 8 W., to T. 35 N., R. 5 W., the dips increase from 30° to 50°. Farther east the dips decrease slightly, and gradually change to west of south on the east side of the basin.

^a Cross, Whitman, La Plata folio (No. 60), Geologic Atlas U. S., U. S. Geol. Survey, 1899.

Along the Laramie outcrop on San Juan River, above Juanita, in T. 33 N., R. 2 W., there are several faults of small longitudinal extent but considerable throw. The largest fault that was observed in the upper part of the Laramie is in the SW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 32. This fault trends N. 25° W. and shows a downthrow of about 125 feet to the southwest. A fault is evident also in the west side of Archuleta Mountain. The only other fault worthy of mention is the one at Monero, N. Mex. This fault strikes S. 26° E. from the northwest corner of sec. 7 to the southern part of sec. 33, T. 31 N., R. 1 E. The displacement amounts to more than 200 feet, the downthrow being on the north side. The disturbance of the rocks in this area has facilitated erosion, and thus the area of workable coal beds is considerably reduced.

THE COAL.

MESAVERDE COAL BEDS IN T. 35 N., R. 8 W.

Locality No. 1: ^a In T. 35 N., R. 8 W., the Mesaverde formation contains six beds. The following section, reading down in stratigraphic order from the upper sandstones, was measured by Joseph A. Taff in the southwestern part of sec. 8:

Section of Mesaverde coal beds in sec. 8, T. 35 N., R. 8 W. (No. 1).

	Ft.	in.
Sandstone, massive.....	30-40	
Sandstone, shaly.....	3	
Coal.....	1	6
Shale and shaly sandstone.....	28	
Coal.....	1	8
Shale.....	12	
Coal.....	2	
Shale.....	8	
Coal.....	1	3
Shale and shaly sandstone.....	12	
Coal.....	1	4
Shale, sandy.....		1
Coal.....	2	
Coal, bony.....		3
Coal.....		10
Shale.....	11	
Coal.....	1	
Sandstone, massive.....		

115-125 11

Locality No. 2: The coal beds given in the section at locality No. 1 can not be definitely identified in other parts of the same township. It is probable, however, that the bed exposed at an old prospect near the center of the north side of sec. 18 is the same as the top bed at

^a These numbers correspond to those on Pl. XXIII.

locality No. 1. The following section was measured by Mr. Taff at the exposure just mentioned:

Section of Mesaverde coal bed in sec. 18, T. 35 N., R. 8 W. (No. 2).

	Ft.	in.
Sandstone, massive.....	35	
Shale.....		6
Coal.....		4
Shale.....		6
Coal.....	1	10
Shale, sandy.....		4
Coal.....		9
Total coal bed.....	3	9

Locality No. 3: In the SE. $\frac{1}{4}$ sec. 7, T. 35 N., R. 8 W., one of the Mesaverde coal beds has been opened at what was formerly known as the Perkins & Rookwood mine. On account of water, a section of the coal bed could not be procured in the abandoned slope, but Mr. Taff gives the following section of another bed 80 feet or more stratigraphically above it:

Section of Mesaverde coal bed in sec. 7, T. 35 N., R. 8 W. (No. 3).

	Ft.	in.
Coal.....		4
Shale.....	1	6
Coal.....	1	6
Shale, carbonaceous.....		4
Coal.....	1	3
Shale and sandstone.....	80	
Covered.....		
Total coal bed.....	4	11

Locality No. 4: In the southeastern part of sec. 8, T. 35 N., R. 8 W., one of the Mesaverde coal beds has been exposed by a drift 25 feet in length. No coal is at present being mined at this point. Mr. Taff gives the following section taken at the face of the drift:

Section of Mesaverde coal bed in sec. 8, T. 35 N., R. 8 W. (No. 4).

	Ft.	in.
Sandstone.....		
Shale.....		6
Coal.....	2	9
Shale.....		3
Coal.....		3
Coal, bony.....		1
Coal.....	2	8
Shale.....		
Total coal bed.....	6	

Locality No. 5: Toward the northeast part of T. 35 N., R. 8 W., the coal beds of the Mesaverde apparently thin suddenly and disappear. However, the last bed observed in passing eastward along the outcrop of the Mesaverde shows a thickness of more than 6 feet. The section was measured at a prospect just north of the Durango wagon road, in the southwest part of sec. 3, T. 35 N., R. 8 W.:

Section of Mesaverde coal bed in sec. 3, T. 35 N., R. 8 W. (No. 5).

Shale, sandy.	Ft.	in.
Coal.....	4	
Shale.....		3
Coal.....		6
Shale.....		2
Coal.....	2	
Shale.		
	6	11

It is the writer's opinion that the bed shown above represents a local thickening.

LARAMIE COAL BEDS.

Locality No. 6: In the Laramie of the Florida River district there are two important coal beds in the shales and thin sandstones immediately above the basal sandstone. These coal beds are usually made up of thin benches of coal separated by shale partings. They are exposed at several places in the southern part of sec. 9, T. 35 N., R. 8 W., at which the following section was measured by Mr. Taff:

Section of coal bed of the upper Laramie in sec. 9, T. 35 N., R. 8 W. (No. 6).

Sandstone.	Ft.	
Coal.....	8	
Shale.....	4	6
Coal.....	2	
Shale, carbonaceous.		
	14	6

Locality No. 7: Near the southeast corner of sec. 9, T. 35 N., R. 8 W., the lower coal bed of the Laramie is exposed in natural outcrop. The section here furnished by Mr. Taff is as follows:

Section of coal bed of the lower Laramie in sec. 9, T. 35 N., R. 8 W. (No. 7).

Shale.	Ft.	in.
Coal.....	2	6
Shale.....	3	
Coal.....	2	
Shale.....	1	6
Coal.....	6	
Shale.....	1	
Coal.....	5	
Shale.		
	21	

Locality No. 8: Below is given a section of a Laramie coal bed in the northern part of sec. 7, T. 35 N., R. 7 W.:

Section of a Laramie coal bed in sec. 7, T. 35 N., R. 7 W. (No. 8).

Shale, carbonaceous, and bone.	Ft.	in.
Coal.....	1	2
Shale.....	1	8
Coal.....		8
Shale.....		8
Coal.....	1	2
Covered; possibly more coal.		
	5	4

There have been local prospects in this vicinity, but no coal is being mined at the present time.

Locality No. 9: Near the center of sec. 8, T. 35 N., R. 7 W., the following section was taken of the upper coal bed of the Laramie:

Section of the upper coal bed of the Laramie in sec. 8, T. 35 N., R. 8 W. (No. 9).

Shale.	Ft.	in.
Coal, with thin shale partings.....	3	
Coal, bony.....		5
Coal with bonystreaks.....	3	
Shale.		
	6	5

Locality No. 10: Near the center of sec. 13, T. 35 N., R. 7 W., a great quantity of Laramie coal is exposed in an old prospect. The identity of this bed could not be determined. The following section was measured in this pit:

Section of Laramie coal bed in sec. 13, T. 35 N., R. 7 W. (No. 10).

Shale, carbonaceous.	Ft.	in.
Coal with thin partings.....	14	
Shale, soft.....	4	
Coal, bony.....	3	
Coal.....	5	6
Shale.		
	26	6

In the upper bed of the above section the coal is apparently of low grade; the thin partings are too numerous and irregular to permit a detailed section. The lower bed, however, is made up of clear coal.

Locality No. 11: In the western part of sec. 17, T. 35 N., R. 6 W., the following section of a Laramie coal bed was obtained:

Section of a Laramie coal bed in sec. 17, T. 35 N., R. 6 W. (No. 11).

	Ft.	in.
Sandstone.....	5	
Shale.....	1	
Coal.....	5	
Coal, bony.....		6
Coal.....	2	4
Sandstone.		
	13	10

Locality No. 12: There have been several prospects and local coal mines along the Laramie boundary in the eastern part of T. 35 N., R. 6 W. The bed in this vicinity is represented by the following section, taken along the south line of sec. 14:

Section of Laramie coal beds in sec. 14, T. 35 N., R. 6 W. (No. 12).

Shale. °	Ft.	in.
Coal.....	2	
Shale.....	15	
Coal.....	4	8
Coal, bony.....		1
Coal.....		5
Shale.....		
	22	2

A sample of the coal bed shown above was taken for analysis by F. C. Schrader in 1905. The sample was obtained by making a cut across the coal bed exclusive of the bony-coal parting. The moisture content is less than in many of the coals in the San Juan region (Durango-Gallup field), but the percentage of ash is far above the average.

Locality No. 13: Along the line between secs. 32 and 33, T. 35 N., R. 5 W., the Laramie coal beds are exposed at several places. There has been some local prospecting in the vicinity. Two beds are exposed, with signs of a third, as shown in the following section, taken at the central part of the east line of sec. 32:

Section of Laramie coal beds in sec. 32, T. 35 N., R. 5 W. (No. 13).

	Ft.	in.
Shale.....	10	
Coal.....	3-6	
Shale.....		2
Coal.....		1
Shale.....		1
Coal.....	1	6
Shale.....		1
Coal.....	7	
Shale.....	25	
Sandstone.....	2	
Coal signs, possibly workable bed.		
Sandstone.....	2	
Shale.....	25	
Sandstone.....	4	
Coal.....	6	
Sandstone, massive, base of Laramie.....	60	

145-148 11

Locality No. 14: In T. 34 N., R. 5 W., there appears to be much coal at the base of the Laramie, but a large amount of it contains hard argillaceous streaks, commonly known as "bone coal." In this region the Tertiary escarpment is near the Laramie outcrop; the

intervening valley shows natural exposures of the coal at several localities. The following section was taken in the northwestern part of sec. 12:

Section of Laramie coal beds in sec. 12, T. 34 N., R. 5 W. (No. 14).

	Ft.	in.
Shale, much burnt.....	4	
Coal.....	2	6
Shale.....	6	
Coal with bony streaks.....	12	
Shale, drab.....	10	
Shale, carbonaceous.....	8	
Sandstone, massive.....		
	42	6

Locality No. 15: About $1\frac{1}{4}$ miles southwest of Piedra Parada Peak, in T. 34 N., R. 4 W., there are two beds exposed above the basal Laramie sandstone. The total thickness of the Laramie as measured in this vicinity is 650 feet. The following is a section of the basal portion, including the coal beds:

Section of Laramie coal beds in sec. 30, T. 34 N., R. 4 W. (No. 15).

	Ft.	in.
Shale.....	12	
Limestone, argillaceous, bearing fossil shells.....		6
Shale, argillaceous, bearing fossil shells at base.....	2	
Coal.....	7	
Shale.....	5	
Sandstone.....	4	
Shale, bearing some fossil shells.....	7	
Limestone, argillaceous, bearing fossil shells.....		7
Shale, with fragments of silicified wood.....	5	
Coal.....	2	2
Shale.....	15	
Sandstone, massive, base of Laramie.....	100	
	160	3

Locality No. 16: Near the center of sec. 16, T. 33 N., R. 3 W., one of the Laramie coal beds is being worked at the Talian mine, on a branch of the Denver and Rio Grande Railroad running from Pagosa Springs to Pagosa Junction. The following is a section of the coal at this mine:

Section of coal beds at Talian mine, in sec. 16, T. 33 N., R. 3 W. (No. 16).

	Ft.	in.
Shale, arenaceous.....		
Coal.....	4	
Sandstone, thin-bedded.....	16	
Sandstone.....	3	
Shale, arenaceous.....		6
Coal.....	3	
	26	6

The upper bed in the above section is the one being mined and is reported to be good coal for steam and domestic purposes. The output of this mine goes largely to the Denver and Rio Grande Railroad, Pagosa Springs, and lumber camps in adjacent portions of the State.

Locality No. 17: Across San Juan River from Montezuma Mountain two workable coal beds are exposed above the basal Laramie sandstone. In the NE. $\frac{1}{4}$ sec. 32, T. 33 N., R. 2 W., the following section was measured:

Section of Laramie coal beds in sec. 32, T. 33 N., R. 2 W. (No. 17).

	Ft.	in.
Shale, sandy.....	25	
Coal, bony.....	1	8
Shale.....	1	
Coal.....	5	4
Shale.....	7	
Coal.....	3	
Shale.....	1	
Sandstone, massive, base of Laramie.....	90	
	134	

Locality No. 18: In the southern part of sec. 2, T. 32 N., R. 2 W., the lowest Laramie coal bed was mined several years ago at what was known as the Archuleta mine. A drift which was run in on the bed, trending S. 50° W. at a very slight dip, is now filled by débris. Schrader^a reports the coal to be of good quality and 11 feet thick, with two thin partings. Shale occurs above and below the coal bed.

MONERO COAL DISTRICT.

The outcrop of the Laramie formation striking east of south across the Jicarilla Apache Indian reservation from Dulce is apparently barren of workable coal beds. The Mesaverde, however, in the vicinity of Monero, N. Mex., contains three workable beds of excellent quality. Monero is located on the Denver and Rio Grande Railroad, in the SE. $\frac{1}{4}$ sec. 7, T. 31 N., R. 1 E. Three companies are operating mines near this place—the Monero Coal Company, the Rio Arriba Coal Company, and the George W. Kutz Company. Most of the coal is sold to the Denver and Rio Grande Railroad, but a small portion goes to the San Luis Valley and some to Santa Fe, N. Mex. The total output for the year 1906 was 43,000 tons, valued at \$69,500.

^a Op. cit., p. 247.

The following is a generalized section from the base of the Mesa-verde up to and including the Monero coal beds:

Section of Mesaverde coal group in Monero district, T. 31 N., R. 1 E.

Covered.	Ft.	in.
Sandstone, brown.....	4	
Bed No. 3 {	Coal.....	1 6
	Shale.....	7
	Coal.....	1 6
Shale.....	3	
Coal.....	1	
Shale and thin sandstones.....	10	
Sandstone, brown.....	1	6
Shale.....	10	
Sandstone, thin bedded.....	30	
Bed No. 2 {	Bone.....	2
	Sandstone.....	6
	Coal.....	3 4
Shale.....	5	
Sandstone.....	15	
Bed No. 1 {	Coal.....	1 8
	Shale.....	9
	Coal.....	1 4
Sandstone and shale.....	15	
Sandstone, massive, base of Mesaverde.....	50	
		155 10

Two analyses of coal from bed No. 2 of this district, as made at the fuel-testing plant, St. Louis, Mo., are given on page 363, Nos. 2121 and 2122. The samples were collected by F. C. Schrader^a in the usual manner, by making a cut across the face of the bed, quartering the sample to convenient size, and sealing it in an air-tight can.

A new mine has recently been opened southwest of Lumberton, in the SE. $\frac{1}{4}$ sec. 8, T. 31 N., R. 1 W. This mine is on a branch line from Lumberton to Elvado and was opened in 1906 by the Burns-Biggs Lumber Company. The thickness of this bed is 3 feet, with sandstone above and shale below.

COAL NORTHEAST OF PAGOSA SPRINGS, COLO.

During the present examination the writer had occasion to visit an area of reported coal about 10 miles northeast of Pagosa Springs, Colo. A prospect from which a small amount of coal has been taken is located in the NE. $\frac{1}{4}$ sec. 36, T. 36 N., R. 1 W. of the New Mexico

^aOp. cit., p. 258.

principal meridian. The following is a section of the horizontal coal-bearing rocks at the prospect:

Section of coal-bearing rocks in sec. 36, T. 36 N., R. 1 W.

Sandstone and shale, largely covered.		
Coal bed, burnt.		Ft. in.
Shale, brown, carbonaceous.....	6	
Covered.....	15	
Shale, carbonaceous.....	14	
Coal.....	5	6
Shale, brown, carbonaceous.....	9	
Coal.....	1	
Shale, carbonaceous.....	1	
Coal.....	1	3
Sandstone, carbonaceous.....	2	
Sandstone, massive, white.....	50	
	104	9

Two coal beds 3 feet or more in thickness are reported by J. E. Chapson, of Pagosa Springs, as occurring above the 5½-foot bed shown in the above section. Possibly one of these beds is represented by the burned zone at the top and the other in the covered area of 15 feet near the top of the section. Coal has been mined for local use at the prospect.

In the eastern part of the SW. ¼ sec. 31, T. 36 N., R. 1 E., there has been some local mining. The bed at this point measures 10½ feet, with shale above and below. The coal has a black, shiny luster, and mines out in rather thin layers.

It is the writer's opinion that the coal beds in the region under discussion are Laramie and have been preserved by block faulting adjacent to the San Juan Mountains. The exposures are within 1 mile of the igneous peaks and 1,000 feet above San Juan River. The coal-bearing rocks are largely covered by talus and spruce. There is evidence of a fault in the vicinity, but no attempt was made to trace the sedimentary boundaries or to map the structure. The coal sections with the massive white sandstone at the base are closely similar to sections on the north side of the main Laramie outcrop, and on this basis alone the identification is made.

For purposes of comparison the analyses of three other samples from the vicinity of Durango are given on page 363. Sample No. 2092 is from bed No. 3, at Porter, and No. 3552 from Perrine Peak. Both of these samples are from coal in the Mesaverde formation. Sample No. 3551 was obtained 3 miles southeast of Durango and is representative of the Laramie coal in this district.

ANALYSES.

The following analyses represent the character of the coal in this field:

Analyses of coal samples from the Durango-Monero coal field, Colorado-New Mexico.

[F. M. Stanton, chemist in charge.]

Name of formation.....		Laramie.		Laramie(?).		Mesaverde.		
Locality.....		Beaver Creek.	Durango.	12 miles north-east of Pagosa Springs		Monero.	Lumberton.	Porter. Durango.
Laboratory No.....		2094.	3551.	4175.	2121.	2122.	5761.	2092. 3552.
Sample as received:								
Prox.	Moisture.....	4.79	3.05	9.50	3.04	3.99	1.71	2.73 3.64
	Volatile matter.....	35.04	32.70	34.78	39.02	39.03	36.26	36.05 37.79
	Fixed carbon.....	45.45	47.47	45.75	48.28	51.04	55.11	54.48 53.35
	Ash.....	14.72	16.78	9.97	9.66	5.94	6.92	6.74 5.22
Ult.	Sulphur.....	.77	1.30	1.14	3.52	1.01	.65	.53 1.36
	Hydrogen.....		4.73		5.57		5.21	5.39
	Carbon.....		64.21		70.72		75.38	75.40
	Nitrogen.....		1.43		1.48		1.56	1.48
Oxygen.....			11.55		9.05		10.28	11.15
Calories.....			6,611		7,185		7,625	7,730 7,553
British thermal units.....			11,900		12,933		13,725	13,914 13,595
Loss of moisture on air drying.....		2.20	.90	2.20	.90	1.50	.....	1.30 1.60
Air-dried sample:								
Prox.	Moisture.....	2.65	2.17	7.46	2.16	2.53	1.32	1.45 2.07
	Volatile matter.....	35.83	33.00	35.56	39.37	39.62	36.40	36.52 38.40
	Fixed carbon.....	46.47	47.90	46.78	48.72	51.82	55.33	55.20 54.22
	Ash.....	15.05	16.93	10.20	9.75	6.03	6.95	6.83 5.31
Ult.	Sulphur.....	.79	1.31	1.17	3.55	1.03	.65	.54 1.38
	Hydrogen.....		4.67		5.52		5.19	5.29
	Carbon.....		64.79		71.36		75.68	76.63
	Nitrogen.....		1.44		1.49		1.57	1.50
Oxygen.....			10.86		8.33		9.96	9.89
Calories.....			6,671		7,250		7,656	7,832 7,676
British thermal units.....			12,008		13,050		13,780	14,098 13,816
Thickness of coal bed.....		<i>Ft. in.</i> 3 2½	<i>Ft. in.</i> 7 3	<i>Ft. in.</i> 5 6	<i>Ft. in.</i> 3 5	<i>Ft. in.</i> 3 4	<i>Ft. in.</i> 2 6	<i>Ft. in.</i> 3 6 10

THE COAL FIELD BETWEEN GALLUP AND SAN MATEO, NEW MEXICO.

By JAMES H. GARDNER.

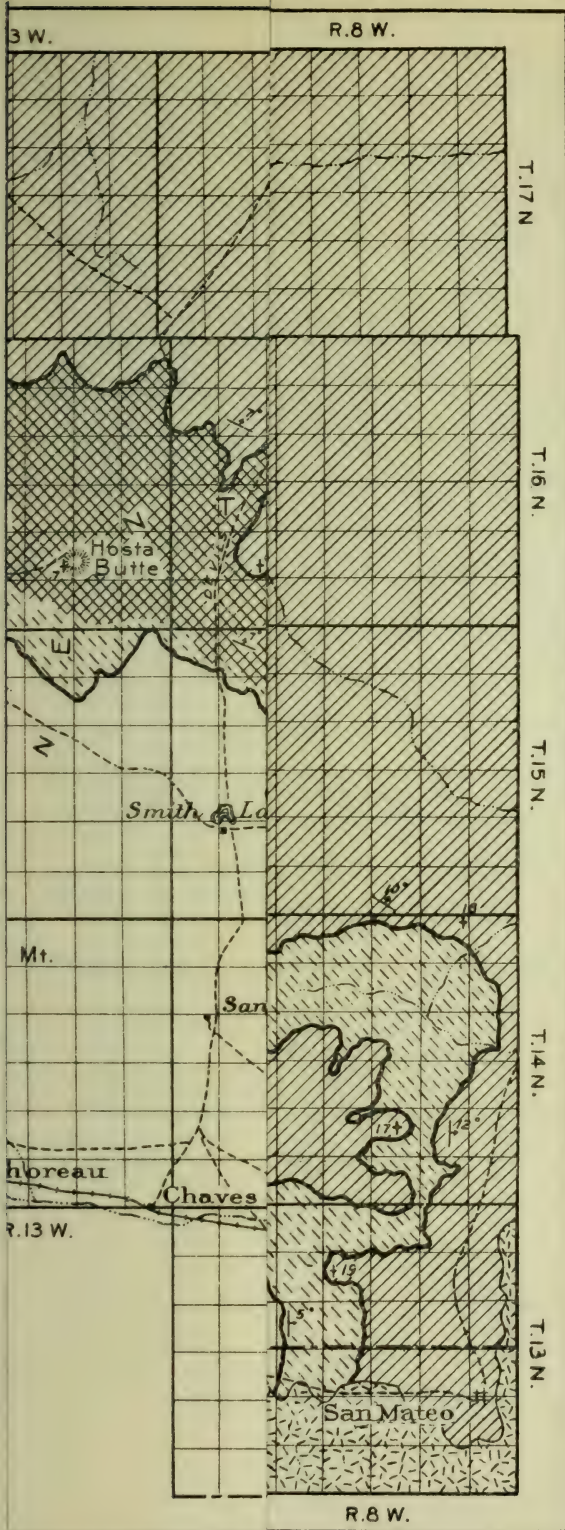
INTRODUCTION.

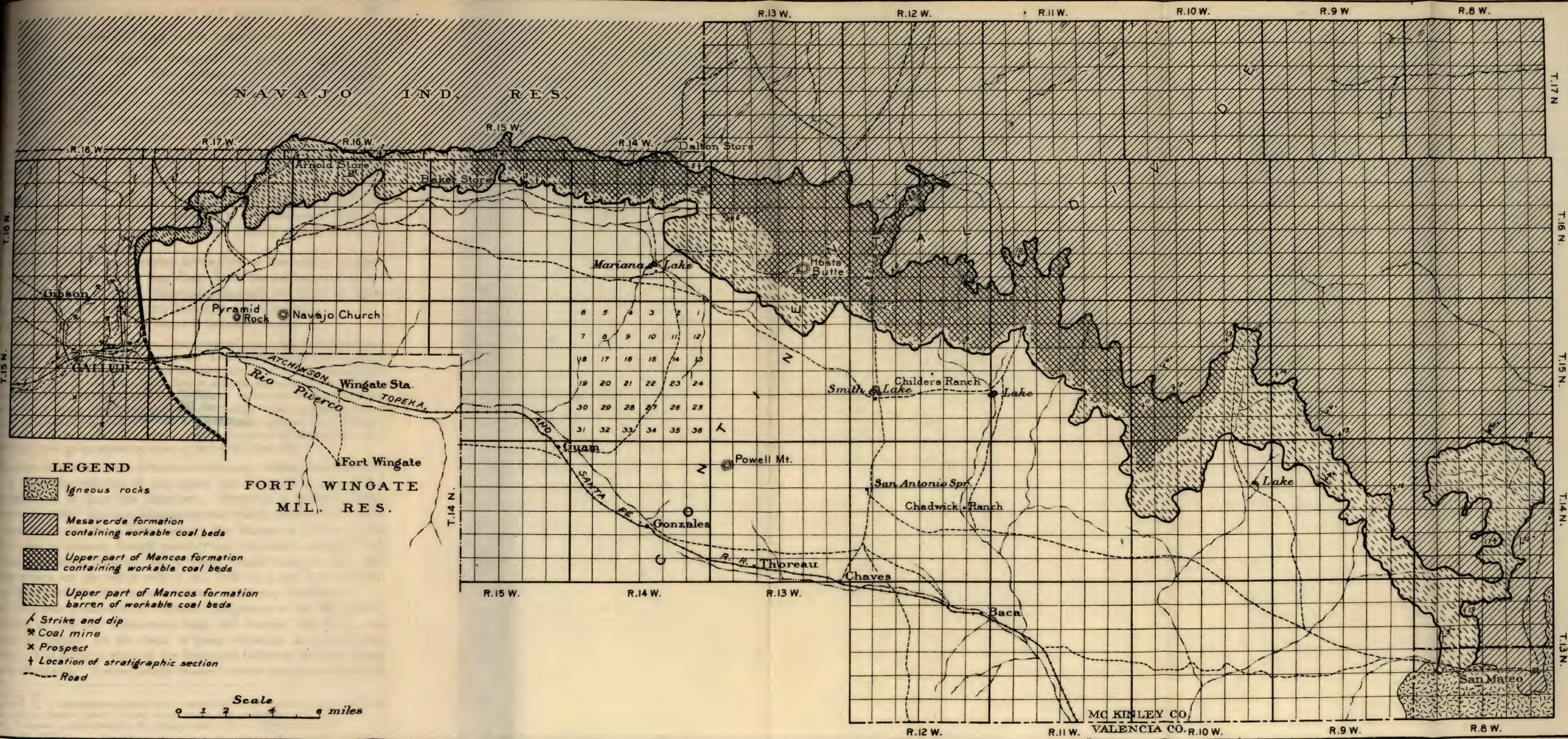
The coal-bearing rocks between Gallup and San Mateo, N. Mex., are included in a portion of the area covered by the hasty reconnaissance of Schrader ^a in 1905. Because of the brief time available for work during the season of 1905, Schrader's party was unable to trace boundaries in detail. The matter of land lines was necessarily ignored to a large extent, as in other parts of the region. The field work of the last season included a resurvey of the area in greater detail and relative to land lines. The map here presented (Pl. XXIV) was prepared by W. J. Reed. Acknowledgment is due also to A. L. Beekly for valuable assistance in the field.

Work was begun at the northeast corner of T. 15 N., R. 18 W., of the New Mexico principal meridian, the township in which Gallup is located, and continued eastward to San Mateo, in T. 13 N., R. 8 W., including a resurvey of that township. The report given here is a brief review of this portion of the San Juan coal region (Durango-Gallup coal field). A full report on the entire field is in preparation, to be published later as a bulletin of the Survey.

The region under discussion is one of sparse population. The lack of permanent streams for irrigating purposes leaves the country practically void of agricultural development. During the fall and spring months there is usually a fair growth of grass over the area and stock may be grazed with profit, but as the grazing season does not continue throughout the entire year and is inconstant in its occurrence, little capital has been invested. There are a few small springs near which are located trading posts, supported largely by Mexicans and Navajo Indians.

^a Schrader, F. C., The Durango-Gallup coal field of Colorado and New Mexico: Bull. U. S. Geol. Survey No. 285, 1906, pp. 241-258.





MAP OF THE COAL FIELD BETWEEN GALLUP AND SAN MATEO, NEW MEXICO
By James H. Gardner, William J. Reed, and Albert L. Beekly

TOPOGRAPHY AND GEOLOGY.

The topographic features are comparatively simple, and the same may be said of the geology. The boundary of the Cretaceous system is expressed in a general way in the topography, which is shown on the Fort Wingate and Mount Taylor topographic sheets of the Geological Survey. On the Fort Wingate sheet a narrow ridge is represented as running in a north-south direction about $2\frac{3}{4}$ miles east of Gallup. The bold portion of this ridge or hogback marks the boundary of the Cretaceous rocks, which dip steeply westward. This hogback stands in bold relief for a few miles northward from the Atchison, Topeka and Santa Fe Railway. Beyond this stretch it swings to the east and is continuous with an escarpment trending in a southeasterly direction by way of Hosta Butte to and beyond the vicinity of San Mateo, in the Mount Taylor quadrangle.

The relation of the coal-bearing formations of this region to those in the northern part of the San Juan River region was not determined in the work of 1905. Schrader classified the rocks in three divisions—upper Montana, lower Montana, and Colorado.

Regarding the Hosta Butte district, Schrader^a says:

The upper coal group [upper Montana] was observed only in the northwestern part of the district, in the southeast corner of the Navajo Indian Reservation, where it has an extent of about 30 miles in an east-west direction. * * * The middle and lower coal groups enter the Hosta Butte district from the direction of Mount Taylor, and after extending northwestward across the district, curve southward and form the hogback, which crosses the railroad 3 miles east of Gallup. Their geologic age is not definitely determined, but from the evidence of a few fossils collected in each of them it is probable that the middle group represents the lower part of the Montana formation and that the lower group represents a part of the Colorado formation.

Schrader shows the three divisions on his map, stating in connection with it that the relation of the upper and lower Montana to the Mesaverde was at that time unknown. However, in Shaler's reconnaissance in 1906,^b the true Mesaverde was traced southward from its type locality in the Mesa Verde, on the Rio Mancos in Colorado, and found to be continuous, though possibly not identical in entirety with the coal groups at Gallup. As a result, Shaler mapped the coal-bearing strata on the south side of the field on a new basis, substituting Mesaverde for the upper and lower Montana of Schrader.

The Colorado formation of Schrader, subjacent to the Mesaverde, consisting of clay and arenaceous shale, and bearing coal beds, was mapped by Shaler, on the basis of fossil evidence, as coal-bearing Mancos. The lower portion of the Mancos is Colorado and the upper portion Montana.^c Consequently Shaler^d shows only two groups of

^a Op. cit., p. 252.

^b Shaler, M. K., A reconnaissance survey of the western part of the Durango-Gallup coal field of Colorado and New Mexico: Bull. U. S. Geol. Survey No. 316, 1907, pp. 376-426.

^c Cross, Whitman, La Plata folio (No. 60), Geologic Atlas U. S., U. S. Geol. Survey, 1899.

^d Op. cit., Pl. XXII.

coal beds between Gallup and San Mateo, the Mancos and the Mesaverde. All the fossils so far collected by previous parties and by the writer during the last season confirm Shaler's determination that the coal beds of the Mancos are limited to the lower part, and consequently are of Colorado age.

Only the lower part of the Mesaverde formation is present in the escarpment between Gallup and San Mateo. The upper portion is eroded for a distance of 40 miles to the north, and forms an escarpment along Rio Chaco roughly parallel with the margin of the field and in close proximity to the outcrops of the Lewis and Laramie formations.

The following table includes the formations of the Cretaceous system exposed between Gallup and San Mateo:

Generalized section of a portion of the Cretaceous rocks between Gallup and San Mateo, N. Mex.

Mesaverde formation, lower part (1,000 feet): Massive sandstone, alternating with thin clay and argillaceous shales and bearing workable coal beds.

Mancos shale (800 feet):

Massive sandstone, arenaceous shale, and coal beds, workable in central part of the area (500 feet).

Drab clay shale and thin sandstones (300 feet).

Dakota sandstone (200 feet): Light-gray, hard sandstone at top and bottom. Alternating thin beds of sandstone and shale, with some bituminous shale and a few irregular coal beds of no commercial importance.

It is probable that the upper part of the Mesaverde, corresponding to the formation along Rio Chaco, is present in the Gallup district and farther southward in the Zuni Basin. Further work will doubtless be necessary before the exact correlation of these rocks can be made.

Regarding the Dakota coal, it seems well to quote the following paragraph of Shaler's report relative to the Gallup district:^a

The coals of the Gallup district represent three formations—the Dakota, Mancos, and Mesaverde. Those of the Mesaverde are the most valuable and the only ones at present mined. The Dakota coal was examined east of Gallup in the southward-facing escarpment north of the railroad, but was found to be thin and full of partings and consequently not of present commercial value.

This character appears to hold for the Dakota throughout the Gallup-San Mateo field.

THE COAL.

There has been no development of the coal beds in most of the field under present discussion, mining being confined entirely to the vicinity of Gallup. For a description of the mines and sections at Gallup, the reader is referred to the Schrader and Shaler reports,

^a Op. cit., p. 410.

previously cited. The present lack of demand for subbituminous noncoking coals in this portion of the country and the recent adoption of fuel oil on the Pacific coast railroads has had a tendency to prevent any marked increase in production in this part of the field. The sections given in the following pages show the number of workable coal beds in the escarpment between Gallup and San Mateo.

Locality No. 1:^a The following section represents the coal-bearing strata, beginning at the base of the Mancos transitional rocks in the central part of sec. 16, T. 16 N., R. 17 W., and extending to the top of the Mesaverde escarpment, at the southeast corner of sec. 6 of the same township:

Section of coal-bearing rocks from sec. 16 to sec. 6, T. 16 N., R. 17 W. (No. 1).

	Ft.	in.
Sandstone, brown, massive.....	30	
Shale and shaly sandstone.....	40	
Sandstone, massive.....	6	
Shale, carbonaceous.....	2	
Coal.....	3	
Shale, carbonaceous.....	3	
Coal.....		6
Shale, carbonaceous.....	6	
Coal.....	2	2
Shale, carbonaceous.....	10	
Shale, drab.....	5	
Coal.....		6
Shale, carbonaceous.....	2	
Shale and thin sandstone.....	15	
Coal.....		6
Shale.....	25	
Sandstone.....	3	
Shale, drab.....	5	
Shale, carbonaceous.....	20	
Shale and thin brownish sandstone.....	150	
Sandstone, gray, massive.....	50	
Shale, carbonaceous.....	10	
Sandstone and shale.....	40	
Sandstone, brown, massive.....	35	
Shale.....	20	
Sandstone, massive.....	20	
Shale and sandstone.....	50	
Shale.....	5	
Coal.....	1	8
Shale.....	10	
Sandstone.....	1	
Shale, carbonaceous.....	1	
Sandstone, gray.....	10	
Coal.....	2	
Shale and sandstone.....	15	

^a These numbers correspond to those on Pl. XXIV.

	Ft.	in.
Sandstone, thin-bedded.....	20	
Shale, carbonaceous.....	1	
Coal.....	2	
Shale, carbonaceous.....	10	
Sandstone, thin, and shale.....	50	
Sandstone, brown, massive.....	20	
Coal.....	1	4
Shale.....		8
Coal.....		8
Shale.....	28	
Sandstone, brown, massive; base of Mesaverde.....	60-100	
Shale, drab.....	20	
Sandstone, massive.....	15	
Shale.....	20	
Sandstone.....	15	
Shale, sandy.....	18	
Sandstone, brown, massive, argillaceous.....	15	
Shale and thin sandstone.....	60	
Sandstone, ferruginous, fossiliferous.....	1	

957-997

Locality No. 2: The following is a section of the Mesaverde coal-bearing rocks near the southwest corner of sec. 35, T. 17 N., R. 16 W.:

Section of Mesaverde coal-bearing rocks in sec. 35, T. 17 N., R. 16 W. (No. 2).

	Ft.	in.
Sandstone, brown, massive.....	70	
Shale, carbonaceous.....	25	
Sandstone, massive, soft.....	30	
Shale.....	1	
Coal.....		5
Shale.....	5	
Sandstone, whitish, massive.....	50	
Shale, drab, hard.....	10	
Coal.....	3	9
Shale, carbonaceous.....	3	
Sandstone.....	60	
Shale, hard, carbonaceous.....	1	8
Coal.....	3	
Shale, drab.....	4	
Coal.....	4	
Shale.....	1	
Coal.....		8
Shale, drab.....	2	
Sandstone, massive.....	4	
Shale.....	1	
Coal.....	1	2
Coal, bony.....		9
Coal.....		4
Shale.....		5
Coal.....	2	1
Shale.....	30	

	Ft.	in.
Sandstone, whitish, massive.....	20	
Coal.....	1	8
Shale.....		2
Coal.....	1	6
Shale.....		3
Coal.....		10
Shale.....	12	
Coal.....	3	4
Shale, drab.....	3	
Covered.....		
	357	

The section given above includes only that portion of the Mesaverde which contains workable coal beds. A series of sandstones, shales, and very thin coal beds occurs below the section given above, continuing on down to and including the upper part of the Mancos.

Locality No. 3: The following is a section of the coal-bearing rocks in the Mancos shale below the Mesaverde, taken at the southeast corner of sec. 3, T. 16 N., R. 15 W.:

Section of Mancos coal-bearing rocks in sec. 3, T. 16 N., R. 15 W. (No. 3).

	Ft.	in.
Sandstone, brown, massive.....	30	
Shale, yellowish, arenaceous.....	30	
Shale, tan colored.....	50	
Sandstone, yellowish.....	6	
Shale and thin sandstone.....	50	
Coal.....	1	2
Shale, dark.....		4
Coal.....		8
Shale, hard, sandy.....	3	
Coal.....		10
Coal, bony.....		4
Coal.....	1	4
Sandstone, gray, argillaceous.....	3	
Shale, carbonaceous.....	2	
Coal, bony.....		8
Shale, drab, and thin sandstone.....	40	
Sandstone.....	15	
Shale.....	12	
Sandstone, massive.....	10	
Coal.....	3	
Coal, bony.....		8
Coal.....	1	
Shale, drab.....	10	
Sandstone.....	1	
Coal, bony.....	1	
Shale.....	15	
Coal.....	2	
Shale, carbonaceous.....	2	
Sandstone.....	1	

	Ft.	in.
Shale, carbonaceous.....	1	
Coal.....	2	6
Shale.....		1
Coal.....	1	1
Shale, sandy.....	3	
Coal.....		8
Shale.....	19	
Sandstone, gray.....	6	
Sandstone, massive.....	40	
Covered.....	100	
Sandstone, massive, soft.....	30	
	496	4

The detailed section given above represents the entire sandstone and coal zone of the Mancos formation. From this place the Mancos is coal bearing eastward to the center of T. 15 N., R. 10 W.

Locality No. 4: The following section of the Mesaverde coal-bearing rocks was measured in the southwest corner of sec. 34, T. 17 N., R. 15 W.:

Section of Mesaverde coal-bearing rocks in sec. 34, T. 17 N., R. 15 W. (No. 4).

	Ft.	in.
Sandstone, brown, massive.....	60	
Shale, gray, and thin sandstone.....	7	
Sandstone, yellowish, soft.....	5	
Shale, gray.....	20	
Sandstone, gray, soft.....	8	
Shale.....	2	
Coal.....		8
Shale.....	4	
Sandstone, white.....		3
Coal.....	1	4
Sandstone, white, soft.....	3	
Sandstone.....	8	
Shale, drab, hard.....	7	
Sandstone, brown.....	4	
Shale, brown.....	10	
Coal.....	3	6
Shale, brown.....	6	
Sandstone, locally burned red.....	15	
Coal.....	7	6
Shale, gray, sandy.....	11	
Coal.....	7	
Shale, gray.....	4	
Coal.....	1	3
Shale, gray.....	4	
Coal.....	6	
Shale, brown.....	4	
Sandstone, massive.....	6	
Shale, brown.....	3	
Coal.....	1	
Shale, gray.....	10	
Sandstone.....	4	

	Ft.	in.
Shale, gray.....	3	
Coal.....	1	3
Shale.....	3	
Sandstone.....	50	
Coal.....	2	
Shale, gray.....	4	
Coal.....		2
Shale, brown and yellow.....	35	
Coal.....		7
Shale, brown.....	1	4
Coal.....		5
Shale, brown.....	25	
Coal.....	1	4
Shale.....	1	
Coal.....		4
Sandstone.....	10	
Coal.....	2	
Sandstone and sandy shale.....	35	
Coal.....	2	
Shale and thin sandstone.....	55	
Sandstone, white, massive.....	14	
Shale, brown.....	3	
Coal.....	2	3
Shale.....	12	
		497. 2

The three workable beds in the upper part of this section, with an average thickness of 6 feet, apparently contain a good grade of sub-bituminous coal, free from partings.

Locality No. 5: In the northern part of sec. 1, T. 16 N., R. 14 W., there are four beds of workable thickness in the upper or Mesaverde formation, as shown in the following section of the coal-bearing portion:

Section of Mesaverde coal-bearing rocks in sec. 1, T. 16 N., R. 14 W. (No. 5).

	Ft.	in.
Sandstone, gray, and shale.....	20	
Shale.....	3	
Coal.....	3	4
Shale, drab.....	40	
Sandstone, gray, soft.....	40	
Coal.....	3	6
Shale, sandy.....	15	
Coal.....	1	
Shale, carbonaceous.....	3	
Sandstone and shale, with thin beds of coal.....	50	
Shale, drab, hard.....	5	
Shale, carbonaceous.....	2	
Coal.....	2	
Shale, sandy.....	20	
Coal with bony streaks.....	4	
Shale, sandy, carbonaceous.....	20	
Covered.....		
		231 10

The coal beds of this section are free from partings and resist weathering fairly well. The 4-foot bed near the base of the section does not present a favorable appearance at the surface exposure. It evidently contains a large percentage of hard, argillaceous material.

Locality No. 6: The following section represents a part of the Mancos shale in the east part of sec. 18, T. 16 N., R. 13 W.:

Section of Mancos coal beds in sec. 18, T. 16 N., R. 13 W. (No. 6).

	Ft.	in.
Top covered.....		
Sandstone, massive.....	5	
Shale, carbonaceous.....	10	
Coal.....		6
Shale, carbonaceous.....	1	6
Coal.....	2	2
Shale, carbonaceous.....	2	
Sandstone and shale.....	6	
Coal.....	1	
Sandstone and thin coals.....	90	
Covered.....		
	118	2

This section shows only one coal bed more than 2 feet in thickness, but it is probable that other beds occur above the section given here, although their outcrop is so covered as to be indistinguishable.

Locality No. 7: Hosta Butte is located on the line between secs. 26 and 27, T. 16 N., R. 13 W. The main portion of this butte is composed of an outlier of the upper or Mesaverde coal group, and the Mancos coal rocks form the escarpment about 1 mile south of the butte. The base of the main butte has an elevation of about 8,000 feet; the top of the escarpment, at a triangulation point used in the survey of the Wingate quadrangle, is at an elevation of 8,837 feet. Just below the 8,000-foot level is a coal bed 2 feet thick, with massive sandstone above and shale beneath. The bed is in the Mancos shale and apparently contains good coal. At an elevation of 8,550 feet occurs a bed 3 feet thick, with carbonaceous shale roof and floor. At 8,600 feet is a bed 5 feet thick, of clear coal, with shale above and below. The two latter coal beds belong in the Mesaverde formation. They are clear of partings or any apparent injurious constituents.

Locality No. 8: Devils Pass is a deep canyon cut through the Mesaverde rocks from sec. 20 to sec. 3, T. 16 N., R. 12 W. The following is a general section taken in the southeast corner of sec. 29 of this township:

Section of Mesaverde coal-bearing rocks in sec. 29, T. 16 N., R. 12 W. (No. 8).

	Ft.	in.
Sandstone, massive.....		
Shale.....	10	
Coal.....	3	6
Sandstones and shale (shale at base).....	25	
Coal.....	3	6
Shale and sandstone.....	10	

	Ft.	in.
Shale.....	8	
Coal.....	1	
Shale and sandstone.....	20	
Coal.....	1	6
Shale.....	1	
Coal.....	1	6
Shale and sandstone.....	100	
Shale, brown, carbonaceous.....	1	
Coal.....	2	
Shale.....	3	
Coal.....	2	
Shale, brown, carbonaceous.....	1	
Shale.....	2	
Shale, brown, carbonaceous.....	1	
Shale and sandstone.....	100	
Shale, brown, carbonaceous.....	1	
Coal.....	1	
Shale, brown, carbonaceous.....	1	
Shale.....	2	
Coal containing much fossil resin.....	2	
Shale, brown, carbonaceous.....	1	
	1	
	306	

Locality No. 9: Near the southeast corner of sec. 11, T. 15 N., R. 12 W., there is one workable bed in the Mancos showing the following section:

Section of Mancos coal bed in sec. 11, T. 15 N., R. 12 W. (No. 9).

	Ft.	in.
Sandstone with intercalated sandy shale.....	4	
Coal.....	3	2
Shale, sandy.....		2
Coal.....		10
Shale, carbonaceous.....	10	
	18	2

A section of this bed measured 3 or 4 miles west of the locality noted above is given in the report of Shaler, who describes it as follows:^a

A typical section of the Mancos coal is exposed in the escarpment south of the entrance to Devils Pass, about 12 miles east of north of Thoreau. The coal compares well in quality with the sample collected in 1905 from the same bed in the Tiejen prospect,^b 10 miles east of north from Baca. The analysis shows a good subbituminous coal. It contains considerable fossil resin, which causes it to ignite readily. The strata * * * dip east of north at an angle of 7°. The section of the coal is as follows:

Section of Mancos coal bed south of Devils Pass.

	Ft.	in.
Shale, drab.....		
Coal.....	2	6
Shale.....		3
Coal.....		10
Shale, brown, carbonaceous.....		
	3	7

^a Op. cit., p. 410.

^b See No. 11 of this report, p. 374.

Locality No. 10: The following is a general section of the Mesaverde or upper coal-bearing rocks, measured in the northwest corner of sec. 29, T. 16 N., R. 11 W.:

Section of Mesaverde coal-bearing rocks in sec. 29, T. 16 N., R. 11 W. (No. 10).

	Ft.	in.
Sandstone, yellow, massive.....	55	
Shale, gray.....	20	
Shale, black, with streaks of bony coal.....	7	
Coal.....		10
Shale, gray.....	5	
Coal.....	2	6
Shale, gray.....	2	
Sandstone, white, soft.....	4	
Shale, brown.....	4	
Coal.....	2	3
Shale, brown.....	2	
Sandstone, white, soft.....	2	
Shale, brown.....	30	
Coal.....	4	
Sandstone, pinkish, soft.....	3	
Shale, soft.....	12	
Sandstone, hard.....	2	
Sandstone, soft, and shale.....	25	
Sandstone, brown, hard.....	3	
Shale, brown.....	4	
Coal.....	1	4
Shale, dark.....	3	
Shale, gray.....	3	
Coal.....	5	2
Shale.....	4	
Coal.....		4
Shale.....	7	
Coal.....	2	
Sandstone, thin bedded.....	3	
Shale, sandy.....	8	
Sandstone.....	18	
Shale, brown.....	8	
Coal.....		10
Coal, bony.....	2	
Sandstone, yellowish.....	4	
Shale, gray.....	3	
Coal.....	2	
Sandstone, thin bedded.....	6	
Shale and soft sandstone.....	38	
Coal.....	2	2
Shale and sandstone, soft.....	32	
Sandstone, tan colored, hard.....	25	
Sandstone, brown, massive, hard.....	35	
Shale, Mancos.....		
	402	5

Locality No. 11: The principal coal bed of the Mancos shale is the Tiejien bed, so named from a small prospect made several years ago

by J. E. Tiejen, of Bluewater, N. Mex. The location of this prospect as given by Mr. Tiejen is in the center of sec. 30, T. 15 N., R. 10 W. A section of the bed follows:

Section of coal bed at Tiejen prospect, sec. 30, T. 15 N., R. 10 W. (No. 11).

	Ft.	in.
Shale, carbonaceous.....	1	
Coal.....	1	3
Shale, arenaceous.....		1½
Coal.....	3	6
Shale, carbonaceous.....		
Total coal bed.....	4	10½

Schrader ^a makes the following statement relative to this coal:

The coal is a good black lignite ^b and contains much fossil resin, resembling in this respect the Monero coal. A sample was taken from the Tiejen prospect for analysis. The material was secured by making a cut across the face of the coal, exclusive of the parting 1½ inches in thickness. * * * With the exception of the heavy percentage of water, this analysis compares favorably with the analyses of other coals of the field.

The analysis of this coal as made at the St. Louis laboratory follows:

Analysis of coal from the Tiejen bed.

[F. M. Stanton, chemist in charge.]

	As received.	Air dried.
Air-drying loss.....	5.20	
Total moisture, including air-drying loss.....	15.03	10.37
Volatile matter.....	37.26	39.30
Fixed carbon.....	41.97	44.27
Ash.....	5.74	6.06
Sulphur.....	.57	.60

In the central portion of T. 15 N., R. 10 W., shown by the broken-lined area on the accompanying map (Pl. XXIV), the Mancos are barren of workable coal beds. Thin beds, however, occur throughout the length of the Mancos exposure. From this vicinity eastward the workable coals are confined to the Mesaverde, which is exposed in a bold, well-marked escarpment striking in a northwest-southeast direction.

Locality No. 12: The following section includes the workable coal beds of the escarpment in sec. 20, T. 15 N., R. 10 W.:

Section of Mesaverde coal beds in sec. 20, T. 15 N., R. 10 W. (No. 12).

	Ft.	in.
Sandstone and shale.....	40	
Shale, brown, hard.....	10	
Coal.....	3	
Shale, brown.....	3	
Coal.....	1	8
Shale.....	8	

^a Op. cit., p. 254.

^b The term "subbituminous" was later adopted by the Survey for this class of coal.

	Ft.	in.
Shale, black, arenaceous.....	3	
Coal.....		6
Shale, drab, hard.....	9	
Coal.....	1	
Shale.....	3	
Sandstone.....	4	
Shale.....	1	
Coal.....	3	6
Shale.....		
	90	8

Locality No. 13: At the southwest corner of sec. 11, T. 15 N., R. 10 W., the coal beds exposed are as follows:

Section of Mesaverde coal beds in sec. 11, T. 15 N., R. 10 W. (No. 13).

	Ft.	in.
Shale, carbonaceous.....	10	
Coal.....	3	3
Shale, carbonaceous.....	15	
Coal.....	2	
Shale, carbonaceous.....	6	
Shale and thin-bedded sandstone.....	100	
Shale, carbonaceous.....	2	
Coal.....	2	
Shale.....	2	
Coal.....	2	
Covered.....		
	144	3

Locality No. 14: In the southwestern part of sec. 19, T. 15 N., R. 9 W., the Mesaverde contains several coal beds which show along the face of the escarpment. These beds vary remarkably, as a comparison of the sections will indicate. Within a few miles thin beds undoubtedly thicken to valuable proportions, and thicker beds thin to mere traces. The following is a section of the coal beds exposed at locality No. 14:

Section of Mesaverde coal beds in sec. 19, T. 15 N., R. 9 W. (No. 14).

	Ft.	in.
Shale, carbonaceous.....	20	
Coal.....	2	3
Shale, carbonaceous.....	15	
Coal.....	1	10
Shale and sandstone.....	12	
Coal.....	1	2
Shale.....	2	
Coal.....	3	1
Shale, carbonaceous.....	4	
Sandstone, brown.....	10	
Shale, drab.....	15	
Coal.....	1	

	Ft.	in.
Shale, carbonaceous.....	10	
Coal containing fossil resin.....	3	
Shale, carbonaceous.....	1	
Coal.....	1	6
Shale.....		2
Coal.....		5
Shale.....	2	
Sandstone and shale.....	25	
Coal.....	2	
Shale, carbonaceous.....	6	
Coal.....		8
Covered.....	139	1

Locality No. 15: A section was made in the southeastern part of sec. 33 of the same township and shows about an equal quantity of coal, although the relations of one bed to another are somewhat different.

Locality No. 16: In sec. 13, T. 14 N., R. 9 W., there are three beds in the escarpment of the Mesaverde worthy of mention. They are shown in the following section:

Section of Mesaverde coal beds in sec. 13, T. 14 N., R. 9 W. (No. 16).

	Ft.	in.
Sandstone.....		
Shale, carbonaceous.....	1	
Coal.....	3	2
Shale, carbonaceous.....	1	
Sandstone, massive.....	10	
Shale, drab.....	4	
Coal.....	3	
Shale, carbonaceous.....	10	
Sandstone, gray.....	18	
Coal.....	2	2
Shale, carbonaceous.....	2	6
Coal.....		10
Shale, carbonaceous.....	55	8

Locality No. 17: In T. 14 N., R. 8 W., the outcrop of the Mesaverde formation makes a decided northward swing; from the east side of sec. 34 it encircles a wide area covering several square miles to the north and returns to the west side of sec. 35 in the same township. From this point the boundary passes westward, showing as a mesa in sec. 9, and thence southward to the point of disappearance beneath the lava surrounding Mount Taylor.

In the central part of sec. 27, T. 14 N., R. 8 W., a coal bed 4 feet 2 inches thick was observed in the Mesaverde formation. The bed is about 20 feet below a massive sandstone, 60 to 100 feet thick, which caps the escarpment at that place.

Locality No. 18: The same bed was observed in the northeastern part of sec. 2, T. 14 N., R. 8 W., where the section is as follows:

Section of Mesaverde coal bed in sec. 2, T. 14 N., R. 8 W. (No. 18).

	Ft. in.	
Shale, sandy.....	10	
Coal.....	2	6
Shale.....		6
Coal.....	1	8
Shale.....	4	
Covered.		
	18	8

Locality No. 19: In the mesa in sec. 9, T. 13 N., R. 8 W., there is only one workable coal bed. This is 3 feet thick, with a carbonaceous shale above and below, and it occurs about 100 feet below the top of the mesa, on the west face. Other thin coal beds are associated with the shales and sandstones above the massive sandstone at the base of the mesa which represents the bottom of the Mesaverde formation.

In the vicinity of San Mateo the dips change from north to east, and as a result the outcrops of the Mancos and Mesaverde formations turn to the south. West of San Mateo the outcrops of these formations pass beneath a lava flow which covers a broad expanse of country to the south and east. It is probable that to the northeast, toward Cabezón, the upper Montana coal group of Schrader is identical with the upper Mesaverde of Rio Chaco and with the highest coal-bearing strata at Gallup.

THE HARMONY, COLOB, AND KANAB COAL FIELDS, SOUTHERN UTAH.

By G. B. RICHARDSON.

INTRODUCTION.

The existence of coal beds of workable thickness in the southern part of Utah has been known since the country was settled by the Mormons in the middle of the last century, but the isolation of the area has prevented development and the southern Utah coal region is the least known in the United States. Only a few small mines have been opened, in the vicinity of settlements that are located contiguous to the coal outcrop, and practically the entire region is unprospected. The recent completion of the San Pedro, Los Angeles and Salt Lake Railroad, however, has aroused interest in this area, and, although the road is 40 miles from the nearest coal, a branch line can easily be constructed across the Escalante Desert between Lund and Cedar City, near the west end of the coal deposits. (See Pl. XXV.)

Very little has been published concerning the coal in southern Utah. Several analyses of samples from the vicinity of Cedar City and Kanarraville were printed in 1883,^a and a number of references ^b to the occurrence of the coal have appeared, but the first systematic study was not undertaken until 1906, when Lee ^c made a preliminary examination of the deposits in Iron County. In the summer of 1907 the writer, assisted by Leon J. Pepperberg, Herbert Graff, and C. D. Perrin, surveyed the Harmony, Colob, and Kanab fields in the western part of the southern Utah coal region; and the present paper is an abstract of a more complete report of this investigation which will be published later.

LOCATION AND TOPOGRAPHY.

That part of the southern Utah coal region which is the subject of the present report is situated in eastern Iron and Washington counties

^a Daggett, E., Analyses and calorific values of some Utah coals: Mineral Resources U. S., U. S. Geol. Survey, 1883, pp. 76-79.

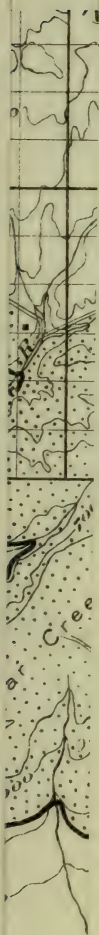
^b Dutton, C. E., Geology of the High Plateaus of Utah, 1880, p. 155. Forrester, R., Coal fields of Utah: Mineral Resources U. S. for 1892, U. S. Geol. Survey, 1893, p. 519. Stanton, T. W., The Colorado formation: Bull. U. S. Geol. Survey No. 106, 1893, pp. 34-37. Storrs, L. S., Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, 1902, pp. 455-456.

^c Lee, W. T., The Iron County coal field, Utah: Bull. U. S. Geol. Survey No. 316, 1907, pp. 359-375.

and western Kane County, and extends from the vicinity of Rush Lake Valley on the west to the Kanab Creek valley on the east. The west end of the region lies at the border of the Basin Range and Plateau provinces, but with the exception of the small Harmony field, the entire coal area is situated in the Plateau Province. The surface of the country ranges in elevation from 5,000 to 11,000 feet above sea level, the general altitude of the country decreasing southward by a series of benches which descend step like from the top of the highest plateaus. In the area under consideration the prominent escarpment known as the Pink Cliffs separates the crest of the High Plateaus, here known as the Markagunt and Paunsagunt, from the next lower bench; and another escarpment, less conspicuous, marks off this from the succeeding platform, the Colob Plateau, which is terminated by the bold escarpment known as White Cliffs. In the western part of the region, toward the border of the plateaus, the White Cliffs fade away and the plateau that is underlain by coal-bearing rocks rises directly above Rush Lake Valley. West of Rush Lake Valley the Harmony Mountains, outliers of the Pine Valley Mountains, form the limit of the area under consideration.

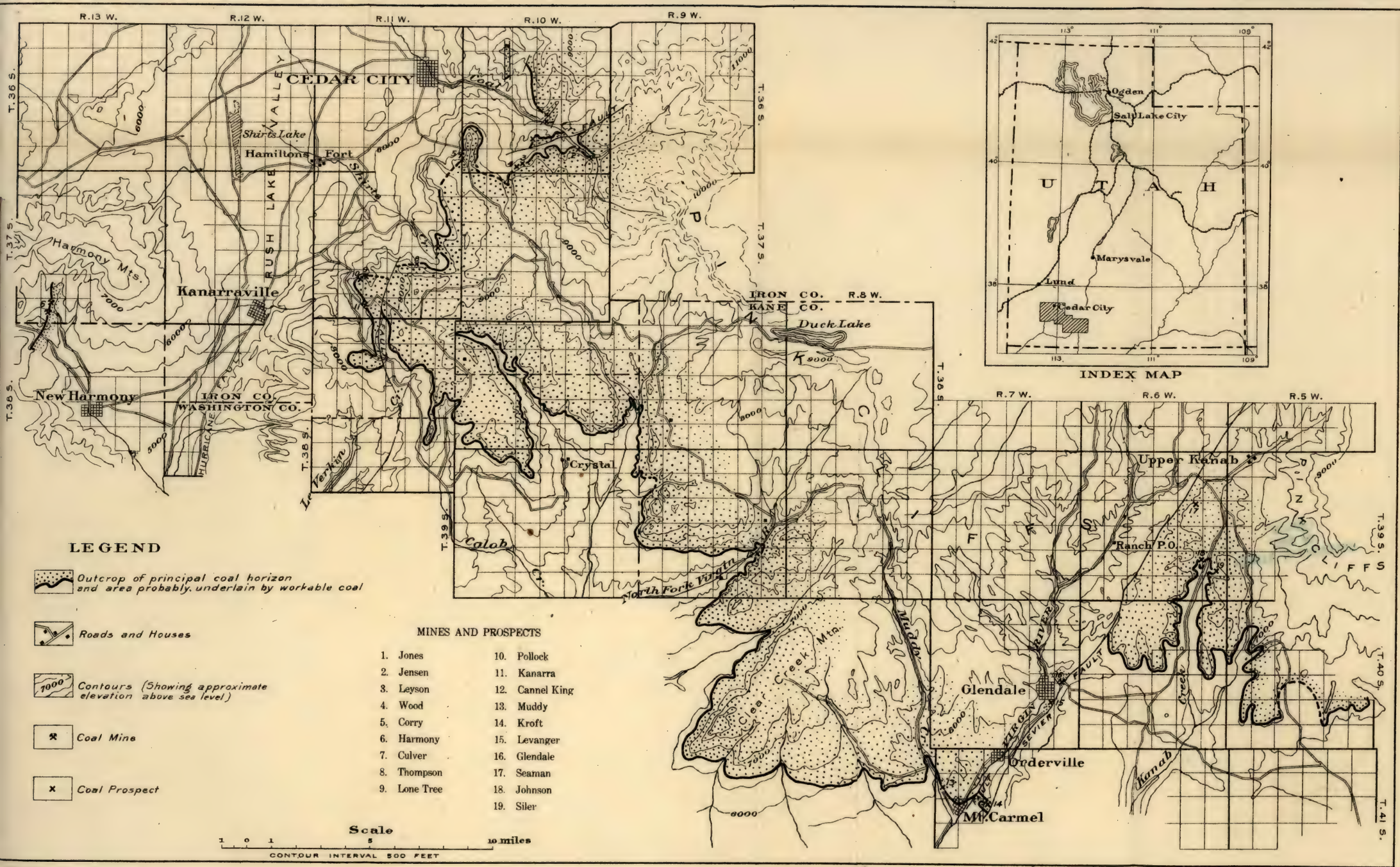
The extreme western portion of the region drains into the Great Basin and has no outlet to the sea; but the larger part is drained by the headwaters of the Virgin River and by Kanab Creek, both of which are tributary to the Colorado. These streams occupy deep valleys, some of them flowing in canyons more than a thousand feet deep, and the region is characterized by some of the grandest scenery on the continent. A large part of the region, consequently, is difficult of access, and much of it is unsuited for settlement; but the relatively broad and low valleys in the eastern and western extremities of the area examined in 1907 are occupied by prosperous towns. Intensive farming is successfully practiced in the valleys, and parts of the Colob Plateau are used as a summer range for sheep and cattle. Snow remains until summer on the highlands, which consequently are well watered and support a forest growth of pine, fir, aspen, cottonwood, etc., so that there is a good supply of timber for mine purposes.

Cedar City, Kanarraville, and New Harmony are situated in or near Rush Lake Valley. Cedar City, with a population of about 1,000, is the largest town in the region and is 33 miles distant from Lund, the nearest station on the San Pedro, Los Angeles and Salt Lake Railroad. Near the east end of the area are the towns of Mount Carmel, Orderville, and Glendale, situated in Long Valley at the head of Virgin River, and Upper Kanab, at the head of Kanab Creek. These towns are most conveniently reached from Marysville, about 90 miles north of Glendale, at the terminus of the San Pete and Sevier branch of the Rio Grande Western Railway. (See Pl. XXV.)



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MAP OF THE HARMONY, COLOB, AND KANAB COAL FIELDS, UTAH
By G. B. Richardson and Leon J. Pepperberg

GEOLOGY.

GENERAL OUTLINE.

A large part of the High Plateaus of Utah is composed of an igneous complex consisting of lava sheets, beds of tuff and volcanic conglomerate, and intrusive masses of various types. These rocks in general overlie an eroded surface of Eocene strata which outcrop at lower elevations around the igneous uplands. Beneath the Tertiary rocks there are several thousand feet of practically horizontal Mesozoic and Paleozoic strata which outcrop at successive lower elevations in a series of benches that extend southward from the High Plateaus to the platform in which Colorado River has cut the Grand Canyon. The Markagunt and Paunsagunt plateaus are underlain by Eocene beds, the southernmost extent of which is marked by their outcrop in the Pink Cliffs. The next succeeding bench is underlain by Cretaceous strata; rocks of Jurassic age underlie the Colob Plateau; and older rocks down to the Carboniferous are exposed along the western base of the plateau. Coal occurs in the lower part of the Cretaceous system and is of Colorado age.

STRATIGRAPHY.

In the southern Utah coal region the rocks are chiefly sedimentary, ranging in age from Carboniferous to Eocene. There are also local intrusive masses and lava flows. As is general throughout the Rocky Mountain province, the coal-bearing rocks are of Cretaceous age, and in the present preliminary report it will suffice to limit the description to the coal measures and to the immediately overlying and underlying formations, which are outlined in the following table:

Outline of coal-bearing and associated rocks in the southern Utah coal region.

System.	Series.	Formation.	Character.	Thickness in feet.
Tertiary.....	Eocene.....	Wasatch.....	Varicolored shale, limestone, sandstone, and conglomerate.	500+
Cretaceous...	Upper Cretaceous..	Unconformity. Montana (?).....	Buff sandstone and drab shale.	500 ±
		Colorado.....	Buff sandstone and drab shale, including workable beds of coal in the lower part.	2,500 ±
Jurassic.....		Unconformity.	Varicolored shale and sandstone, with lenses of limestone and gypsum overlying massive marine limestone.	800 ±

The coal-bearing strata are underlain by about 800 feet of generally soft rocks, which outcrop in a lowland belt below the Cretaceous platform. These lower rocks are composed of reddish and varicolored shale and thin-bedded sandstone, with intercalated beds and

lenses of gray limestone and white gypsum, and about 400 feet of massive gray limestone at the base. Marine Jurassic fossils occur abundantly in the lower limestone, but no remains of life have yet been found in the upper strata. The lithology and stratigraphic relations of these upper rocks suggest, however, their equivalence to the fresh-water Jurassic beds (Morrison) that are well developed in other parts of the Rocky Mountain region. These rocks are delimited above by an erosional unconformity, marked by the varying thickness of the Jurassic and by a basal Cretaceous conglomerate.

Throughout the Plateau Province Lower Cretaceous time is unrepresented by rocks, and Upper Cretaceous strata lie directly upon beds of Jurassic age. In the area under consideration the Upper Cretaceous rocks consist of about 3,000 feet of buff sandstone and drab shale, in the lower part of which coal beds of workable thickness occur. No Dakota fossils have been found in this area, although possibly the thin bed of conglomerate at the base of the Cretaceous is of that age. The greater part of the Cretaceous rocks, including the coal, are assigned to the Colorado, but the upper few hundred feet contains fresh-water shells and plants of undetermined age, which may possibly belong to the Montana. The succession of Cretaceous strata in the southern Utah region is unlike that in western Colorado and northeastern Utah, so that the formation names used in the coal fields of those areas can not be applied to the rocks in the area under consideration. The coal in southern Utah is older than that in the Uinta Basin region, which includes the Book Cliffs field, the largest and most important in the State. The southern Utah coal belongs to the same group as that in the Weber River field.

The Cretaceous rocks are unconformably overlain by Eocene strata, which, as already stated, outcrop in the Pink Cliffs and underlie the Markagunt and Paunsagunt plateaus. The unconformity, marked by a basal conglomerate containing pebbles of the underlying rocks, is emphasized by the absence of the upper members of the Cretaceous system, which are well developed in other parts of the Plateau province. The Eocene rocks consist of a variable succession of shale, limestone, sandstone, and conglomerate that are characteristically varicolored. Shades of red and white predominate and are beautifully developed in the Pink Cliffs. Fossils are extremely rare in these rocks, and only a few fragments of *Vivipara* and *Unio* have been obtained in this area; but the characteristic peculiarities of stratigraphy and coloring of the rocks leave little room for doubt that, except possibly a few feet of basal beds containing conglomerate of doubtful significance, they belong to the Wasatch formation of the Eocene series, which is so largely developed in the High Plateaus of Utah and from which characteristic fossils have been obtained in a number of places.

Igneous rocks cover a large part of the surface of the High Plateaus north of the coal fields, but in the area under consideration they are comparatively rare. The common type is basalt, which occurs in lava flows on an eroded surface of the sedimentary rocks from those of Eocene age downward. Over most of the area these igneous rocks apparently have had no effect on the coal, but in the Harmony field an intrusive mass of andesite has accomplished considerable metamorphism.

STRUCTURE.

Throughout the greater part of the area included in the present report the rocks dip between 1° and 2° NE.; but along the western margin of the Plateau Province the structure is complex and the strata are steeply tilted, and north of New Harmony the coal measures adjacent to a mass of intrusive igneous rock dip eastward at high angles. The continuity of the strata is interrupted by a number of normal faults of large displacement. One of these, the Hurricane fault, extends along the western border of the plateau and has been traced southward as far as the Grand Canyon in Arizona. In consequence of this fault the coal in the Colob field occurs about 2,000 feet higher than that in the Harmony field. Several displacements, in general parallel to the Hurricane fault, occur east of it, and in the vicinity of Cedar City especially the rocks are much disturbed. Another important fault is the Sevier, which extends along the upper valley of Virgin River east of Orderville and Glendale. This displacement has been traced for many miles, both north and south, beyond the limits of the area represented by the map (Pl. XXV). Within the region here discussed the throw of the Sevier fault amounts to about 2,000 feet, the downthrow, as is common throughout the plateau region, being on the west. This fault causes a lateral offset of the coal outcrop of 9 miles, extending from the vicinity of Mount Carmel to a point north of Glendale.

THE COAL.

OUTLINE OF OCCURRENCE.

Coal occurs throughout the area examined in the lower part of the Cretaceous system between 50 and 500 feet above the top of the Jurassic rocks. In general, in any one section only one bed of workable coal has been found, but in places six are present. The beds of coal thicken and thin out like lenses, and no single bed has been found to be continuous for more than a few miles. In the absence of prospecting, however, many facts relating to the occurrence of the coal are unknown. It is estimated, on the assumption that the workable limit of the coal is 4 miles back from the outcrop, that there are 295 square miles of coal land in the area examined in 1907.

If the entire thickness of coal may be represented by a single bed 8 feet thick, the total amount in this area is 2,672,803,840 short tons.

The present development of the western part of the southern Utah coal region is limited to the few small mines and prospects shown on the map. The mines are worked only during the fall and winter months, to supply the local demand, and the entire output is only a few hundred tons a year. When a railroad enters the field, this coal may compete with others in the southern California market, with the advantage of being the nearest of the Rocky Mountain fields.

That part of the southern Utah coal region with which the present report is concerned is divided into the Harmony, Colob, and Kanab fields, which are distinctly separated topographically.

HARMONY FIELD.

The Harmony coal field is the best known though smallest in the southern Utah region. The coal outcrop is only about 3 miles long, and the field has been prospected by a number of pits, tunnels, and shafts.

LOCATION.

The Harmony field lies partly in Iron County and partly in Washington County, in secs. 29 and 32, T. 37 S., R. 13 W., and in unsurveyed land in the adjoining township to the south. This area is a hilly country between the Pine Valley Mountains on the southwest and the Harmony Mountains on the northeast, and is drained by branches of Harmony Creek. The coal in the Harmony field is as accessible as any other in the entire region and is much more easily reached than the coal in the greater part of the region. The principal prospects are situated 4 miles northwest of New Harmony, at an elevation of about 6,000 feet, and are reached by a wagon road up Pace Creek. New Harmony is connected with Cedar City, 20 miles to the northeast, by a good wagon road across a broad wash-covered area.

OCCURRENCE AND THICKNESS OF COAL.

The coal in the Harmony field occurs in a narrow belt of Cretaceous strata which outcrop along the eastern base of a low range of hills composed of andesite. The coal-bearing rocks contain abundant fossils of Colorado age and are correlated with the coal measures on the Colob Plateau, but neither the fossils nor the rocks are sufficiently distinctive to determine the exact horizon that is here represented as compared with the section on the plateau. Only about 600 feet of Cretaceous rocks, consisting of alternating layers of drab shale, buff sandstone, lenses of gray limestone, and several beds of coal, are exposed in the Harmony field. These rocks are unconformably overlain by Eocene rocks and they are delimited below by

an intrusive mass of andesite which has tilted the strata and metamorphosed the coal.

The rocks adjacent to the andesite and extending eastward from it for about half a mile dip to the east at angles ranging from 45° to 80°. East of this steeply tilted zone the dips become less, and in the Harmony Mountains the strata lie almost flat. In the valley of Pace Creek, where the change in dip occurs, the relations are concealed by abundant vegetation and by accumulations of rock débris, but a few exposures show disturbed conditions, and it is probable that faulting has occurred. Whether the coal continues but little disturbed east of the Pace Creek valley or has been cut off by a considerable fault can best be determined by drilling.

The following section of coal-bearing rocks in the Harmony field was measured during the past summer:

Section of coal-bearing rocks in the Harmony field, Utah.

	Feet.
Shale, buff.....	65
Sandstone, buff.....	4
Shale, buff.....	50
Coal and shale (No. 1).....	7
Shale, drab.....	36
Coal and shale (No. 2).....	11
Sandstone, buff.....	1
Covered (shale?).....	30
Shale, drab.....	8
Coal and shale (No. 3).....	6
Shale, drab.....	10
Covered (shale?).....	25
Limestone, fossiliferous.....	5
Coal and shale (No. 4).....	11
Sandstone, buff.....	2
Shale, drab.....	25
Sandstone, buff.....	3
Covered (shale?).....	35
Shale, drab.....	18
Sandstone, buff.....	5
Shale, drab.....	18
Covered (shale?).....	25
Sandstone, buff.....	10
Shale, drab.....	16
Coal and shale (No. 5).....	17
Limestone, gray.....	5
Sandstone, buff.....	3
Shale, carbonaceous.....	10
Coal and shale (No. 6).....	6
Shale, drab.....	15
Sandstone.....	8
Shale, carbonaceous.....	20
Concealed.....	50
Intrusive andesite.....	
	560

R. A. Kirker, who has spent several years in prospecting this field, numbers the coal beds from 1 to 6, the latter being at the base of the section, and states that the coal ranges from 4 to 7 feet in thickness, as follows:

Thickness of coal beds in the Harmony field, Utah.

[Measured by R. A. Kirker.]		Ft. in
Bed 1.....	4	
Bed 2.....	5	
Bed 3.....	4	8
Bed 4.....	4	4
Bed 5.....	7	
Bed 6.....	4	

The measurements for beds 3 and 4 were confirmed by the writer, but the conditions of the workings were such that the other beds could not be measured with accuracy.

The steep dip of the coal-bearing rocks and the close proximity of the ground-water level to the surface will cause trouble in developing this field, but apparently the chief drawback is the dirty condition of the coal, as shown by the large amount of ash in the analyses. Although considerable prospecting has been done in the Harmony field, active mining has not yet begun. It is reported, however, that a Los Angeles company plans soon to develop the property.

QUALITY OF THE COAL.

The coal in the Harmony field has been metamorphosed by the intrusion of a large mass of andesite into the coal-bearing rocks. The andesite occupies an area of many square miles west of the coal field, and its intrusion has steeply tilted the strata adjacent to the contact, as already mentioned. In the SW. $\frac{1}{4}$ sec. 32, T. 37 S., R. 13 W., the intrusive rock is in close proximity to the coal, but the actual contact was not seen nor was any evidence obtained that the coal has been coked. In other places the outcrop of the andesite is several hundred feet distant from the nearest coal bed. The analyses show that considerable alteration of the coal has occurred, and, as would be expected, that the beds which are farthest away from the andesite are the least altered. Unless the intrusive rock extends eastward beneath the surface, it is probable that the higher grades do not extend far from the outcrop.

The coal in the Harmony field is deep black in color and has a brilliant luster. It breaks both with a semiconchoidal and a cubical fracture, and is fairly hard, though it can be crushed in the hands. The coal is streaked with seams of bone and shale in intimate association, and, at least locally, much foreign matter is present. Films of iron pyrite occur, irregularly disseminated. The coal burns with but little smoke and with a faint blue flame.

The composition of coal from the Harmony field is shown by the analyses on page 388, made at the fuel-testing plant of the United States Geological Survey at Pittsburg, Pa., by uniform methods,^a under the direction of N. W. Lord and F. M. Stanton.

The analysis of each sample is tabulated in two forms, showing the analysis of the sample as received and that of the air-dried sample. The two sets of figures show the composition of the same sample under different conditions, and the difference in the figures emphasizes the necessity of stating with each coal analysis exactly what it represents. The analysis of the "sample as received" shows the percentage of the several constituents in the coal, including the amount of water contained by the coal as mined. The analysis of the "air-dried sample" shows the percentage of the several constituents in the coal after it has been powdered and allowed to lose the moisture that evaporates on exposure in an oven heated to a temperature slightly above that of the laboratory until a constant weight results, the percentage of air-drying loss being shown in the table. For general purposes the figures for the air-dried sample are best for comparison with other analyses.

The analyses show an extremely high percentage of ash, ranging from 22.89 to 33.96 per cent in the air-dried samples. These high values are due to the intimate association of shale and foreign matter with the coal. Better results are obtained from picked samples. Three small samples selected by Mr. Kirker and analyzed by Herman Harms, State chemist of Utah, showed respectively 11.65, 12.61, and 13.83 per cent of ash, and two small lumps of coal from bed 6, chosen to show low ash values, were found to contain 8.90 and 9.46 per cent of ash by G. O. Spitler, of the United States Geological Survey. The amount of coal containing such relatively low proportions of ash has not been determined. If by washing or by other means the product of this field can be put on the market with a much lower percentage of ash than shown by the analyses on page 388, the Harmony coal will rank as a high-grade fuel. The high ash content is the cause of the low heating values, which range from 8,569 to 10,796 British thermal units, as shown in the table.

Bed 6, the one nearest the andesite, has a fuel ratio of 13.16, which on that basis classes the coal as an anthracite. The fuel ratios of beds 3 and 4 range from 5.88 to 3.39, which would class them from low-grade semianthracite to semibituminous coals. The high percentages of carbon (82.06 to 88.53) in the ultimate analyses calculated on an ash-free, moisture-free basis emphasize the metamorphosed condition of the Harmony coals.

^a Prof. Paper U. S. Geol. Survey No. 48, 1906, pp. 174 et seq.

Analyses of coal samples from the Harmony coal field, southern Utah.

No. of coal bed.....		Bed 6.	Bed 4.	Bed 3 (picked sample).	Bed 3.
Laboratory No.....		5311	5312	5310	5309
Sample as received:					
Prox.	Moisture.....	8.21	7.02	9.50	8.29
	Volatile matter.....	4.41	10.30	13.22	13.44
Prox.	Fixed carbon.....	58.02	60.61	49.22	45.64
	Ash.....	29.36	22.07	28.06	32.63
Ult.	Sulphur.....	2.28	4.06	3.55	3.17
	Hydrogen.....	2.98	3.32	3.44	3.55
Ult.	Carbon.....	53.31	62.77	51.44	48.48
	Nitrogen.....	.90	.92	.85	.85
Ult.	Oxygen.....	11.17	6.86	12.66	11.32
	Calories.....	4,949	5,782	4,922	4,575
British thermal units.....		8,908	10,408	8,860	8,235
Loss of moisture on air drying.....		5.20	3.60	5.70	3.90
Air-dried sample:					
Prox.	Moisture.....	3.17	3.55	4.03	4.57
	Volatile matter.....	4.65	10.69	14.02	13.99
Prox.	Fixed carbon.....	61.21	62.87	52.19	47.49
	Ash.....	30.97	22.89	29.76	33.95
Ult.	Sulphur.....	2.41	4.21	3.76	3.30
	Hydrogen.....	2.53	3.03	2.98	3.25
Ult.	Carbon.....	56.23	65.12	54.55	50.45
	Nitrogen.....	.95	.95	.90	.88
Ult.	Oxygen.....	6.91	3.80	8.05	8.17
	Calories.....	5,220	5,998	5,219	4,761
British thermal units.....		9,397	10,796	9,395	8,569

COLOB FIELD.**LOCATION.**

The Colob coal field includes the coal on the bench immediately above the Colob Plateau. It extends from the vicinity of Cedar City and Kanarraville, at the west end of the plateau, southeastward to the Sevier fault in the vicinity of Glendale and Mount Carmel, in the upper Virgin Valley. The outcrop of the coal beds follows a tortuous course around the dissected margin of the plateau and throughout the larger part of the area occurs in the face of steep cliffs and is difficult of approach, but where the coal passes beneath the surface in the valleys of the larger streams it is more easily accessible. In the eastern part of the field, especially, and locally at the extreme west the coal can be conveniently reached. In the central part of the Colob field, however, the problem of transporting the coal from its outcrop in the face of cliffs across the dissected upland presents many difficulties.

OCCURRENCE AND THICKNESS OF COAL.

The coal in the Colob field occurs in the lower few hundred feet of the Cretaceous section in rocks of Colorado age. Several beds have been found at different horizons, but the field has been prospected in only a few places and much remains to be learned concerning the occurrence of the coal. The work of the last season demonstrated, however, that no bed can be traced continuously throughout

the field, and that the coal occurs in beds of variable extent which are lenslike in their development. Coal has been found near the base of the Cretaceous rocks wherever sections have been made, and it is probable that the entire area marked on the map by stippling is underlain by one or more beds of coal. In prospecting it will be convenient to bear in mind that the coal occurs in the lower part of the buff and drab sandstone and shale series, usually within 200 feet of the underlying red and varicolored shales and gypsum.

The rocks on the Colob Plateau lie almost flat, dipping northeastward at an angle of only 1° or 2° . Along the margins of the field the rocks are traversed by normal faults of large displacement. The Sevier fault, at the east end, is of such magnitude that it causes a lateral displacement of the coal of about 9 miles, and forms the boundary between the Colob and Kanab fields.

The following measurements of the coal in the Colob field begin in the vicinity of Cedar City and proceed southeastward, following the crop around the field. (See Pl. XXV.) Several layers of thin-bedded, marly shale and limestone are associated with the coal, both above and below. They contain numerous small gasteropods, popularly known as screw shells, which serve as a guide in prospecting.

No successful coal mines have been located on the north side of Coal Creek, and apparently beds of workable thickness do not extend north of this stream. Two prospects near the mouth of Maple Creek, in sec. 22, T. 36 S., R. 10 W., show that the coal has many partings, and it is probably too "dirty" to be worked with profit. A section at the prospect on the west side of the creek is as follows:

Section at prospect in the SW. $\frac{1}{4}$ sec. 22, T. 36 S., R. 10 W.

Limestone, fossiliferous.	Ft.	in.
Coal.....	8	
Shale.....	3	
Coal.....	1	2
Bone.....	1	
Coal.....	10	
Shale.....	2	
Coal.....	11	
Shale.....	1	
Coal.....	7	
Shale.....	6	
Coal.....	2	
Total coal.....	6	2

At the head of and south of Coal Creek, however, coal occurs in workable thickness, and a number of prospect pits and small mines have been opened to supply the demand for domestic coal in Cedar City.

The Jones mine (No. 1^a) is situated in the NW. $\frac{1}{4}$ sec. 36, T. 36 S., R. 10 W., about 25 feet above Coal Creek and adjacent to a good wagon road. Like all the workings in this field, this mine consists of a tunnel driven in on the outcrop for 100 feet, more or less. The following section was measured in the mine:

Section of coal bed at Jones mine.

	Ft.	in.
Limestone, fossiliferous.		
Shale, carbonaceous.....	1	
Coal.....	1	8-12
Bone.....		1- 4
Coal.....	2	3-12
Shale, carbonaceous.....		3
Limestone, fossiliferous.		
Total coal.....	5±	

The Jensen mine (No. 2) is an abandoned drift about three-fourths of a mile northwest of the Jones property, in the NE. $\frac{1}{4}$ sec. 35, T. 36 S., R. 10 W. The workings were inaccessible in the summer of 1907, and the thickness of the coal was not determined.

A fault apparently causes an offset of the coal in secs. 27 and 28, as shown on the map, where the vertical displacement between two beds of coal, presumably the same, is indicated as about 700 feet. At a prospect in the downthrown block in the SE. $\frac{1}{4}$ sec. 28, T. 36 S., R. 10 W., the following section was measured:

Section of coal bed in prospect south of Coal Creek.

	Ft.	in.
Shale.		
Coal.....		6
Bone.....		4
Coal.....	3	
Bone.....	1	
Coal.....		10
Limestone, fossiliferous.		
Total coal and bone.....	5	8

A number of prospects have been opened on the coal in sec. 33, T. 36 S., R. 10 W. The abandoned Leyson mine (No. 3) is reported to have been the earliest opened in this field, and to have been worked between 1854 and 1890. Daggett^b states that the bed in this mine is split by a clay parting into an upper bench 2 feet thick and a lower one 4 feet thick.

At the Wood prospect (No. 4), about half a mile to the south, the following section was measured by W. T. Lee:

^a The numbers refer to location of mines and prospects on Pl. XXV.

^b Daggett, E., Analyses and calorific values of some Utah coals: Mineral Resources U. S., U. S. Geol. Survey, 1883, p. 77.

Section of coal bed in Wood mine.

	Ft.	in.
Limestone, fossiliferous.		
Coal, bony.....	2	
Clay.....		5
Coal.....		10½
Shale, carbonaceous.....		1
Coal.....		6
Clay.....		3½
Coal.....	2	1
Clay.....		1
Coal.....	2	1
Limestone.		
Total coal.....	7	6½

These two mines are situated about 2,000 feet above Cedar City, and consequently are difficult of approach.

The Corry mine (No. 5) is situated on the west side of Mount Henry about 4 miles southeast of Cedar City, at an elevation of about 2,700 feet above the town, and is one of the main sources of supply. The following section was measured here:

Section of coal bed in Corry mine.

	Ft.	in.
Limestone, shaly, fossiliferous.		
Coal.....	3	3
Bone.....		9
Coal.....	2	4
Clay.....		6
Coal.....		10
Limestone, shaly, fossiliferous.		
Total coal and bone.....	7	2

South of the Corry mine the coal is covered by a mass of basaltic lava, but the bed outcrops again in the amphitheater at the head of Shirtz Creek. Several old prospect holes are situated there, but only one opening, the Culver mine (No. 7), is now accessible. The coal is about 10 miles distant from Cedar City and nearly 3,000 feet above it, and is reached by a steep road. The following section was measured in this mine:

Section of coal bed in Culver mine.

	Ft.	in.
Limestone, fossiliferous.		
Shale, carbonaceous.....		4
Coal.....	2	3
Bone.....		2
Coal.....	4	11
Clay.....		7
Coal.....		9
Limestone, fossiliferous.		
Total coal and bone.....	8	1

South of Shirtz Creek the coal outcrop is also covered by a sheet of lava, and where it next appears, east of Kanarraville, a fault probably divides the coal measures and causes an apparent repetition of the coal. The dislocation is suggested by the occurrence of two beds of coal with fossiliferous limestone above each, in secs. 8 and 10, T. 38 S., R. 11 W., but the actual existence of the fault has not been demonstrated. However, 5 miles farther south, at the end of the area mapped, a fault which causes an estimated displacement of 500 feet in the massive red sandstone and overlying Jurassic limestone is plainly visible, and the suspected fault in the coal measures appears to be the northward continuation of this displacement.

Several prospect pits and small mines have been opened on the plateau east of Kanarraville, where the coal is at an elevation of about 3,000 feet above the town. Two old mines, known as the Lone Tree (No. 9) and Pollock (No. 10), were caved in when visited in 1907. Daggett^a reported in 1883 that 8 feet of coal was exposed in the Lone Tree mine, and 14 feet 3 inches in the Pollock mine. At present the Kanarra mine (No. 11) is the only one that is worked. This is located on the road from Kanarraville across the plateau, and consists of a drift about 200 feet long, with several rooms off the main entry which are now caved in. The following section was measured at the mouth of the entry:

Section of coal bed at Kanarra mine.

	Ft.	in.
Limestone, shaly, fossiliferous.....	4	
Shale, carbonaceous.....		2
Coal.....	8	9
Shale, carbonaceous.....		7
Sandstone, buff.		

Between the Kanarra mine and North Fork of the Virgin, an air-line distance of 18 miles and a distance along the outcrop of more than 40 miles, the coal is unprospected and very little is known regarding it. Throughout this distance the coal outcrops for the most part in the face of steep cliffs and is difficult of approach. Wherever sections were measured during the survey in 1907 one or more beds of coal were encountered, the indications being that the coal occurs in lenses which thicken and thin. No single bed could be recognized as such for any considerable distance.

The following measurements show general conditions:

Section of coal beds in sec. 8, T. 38 S., R. 11 W.

	Ft.	in.
Coal.....	4	
Covered.....	15	
Sandstone, massive, buff.....	35	
Sandstone, thin bedded.....	10	

^a Op. cit., pp. 77-78.

	Ft.	in.
Shale, calcareous and carbonaceous.....	15	
Limestone, fossiliferous.....	6	
Coal.....	4	
Shale.....		4
Coal.....	1	6
Shale.....		4
Coal.....	3	8
Shale.....		4
Limestone, fossiliferous.....	1	4
Coal.....	1	6
Shale.....		4
Coal.....	1	
Shale.....		
Total coal.....	15	8

Section of coal beds in sec. 13, T. 38 S., R. 11 W., at the head of Colob Creek.

	Ft.	in.
Shale, sandy.....		
Limestone, thin bedded, fossiliferous.....		10
Coal.....	4	2
Shale, drab.....		$\frac{1}{2}$
Coal.....	1	5
Shale.....	1	3
Coal.....		1
Sandstone.....	10	
Total coal.....	5	8

Section of coal beds in sec. 14, T. 38 S., R. 11 W.

	Ft.	in.
Shale, carbonaceous.....	12	
Limestone, fossiliferous.....	1	
Coal.....	4	
Shale.....	2	2
Sandstone, buff.....	35	
Shale, sandy.....	6	
Sandstone, buff.....	12	
Shale, carbonaceous.....	10	
Limestone, fossiliferous.....	10	
Coal.....	1	6
Shale.....		3
Coal.....	4	11
Shale, carbonaceous.....		6
Sandstone, fossiliferous.....	2	6
Coal.....		11
Shale, carbonaceous.....	4	
Total coal.....	11	4

Section of coal bed in sec. 5, T. 39 S., R. 10 W.

	Ft.	in.
Limestone, fossiliferous.....		
Coal.....	3	4
Shale, carbonaceous.....		

Section of coal bed in sec. 7, T. 39 S., R. 9 W.

Sandstone.		Ft.	in.
Coal.....	1	2	
Shale.....	1		
Sandstone, buff.....	30		
Covered (probably shale).....	35		
Shale, carbonaceous.....	45		
Coal.....	6	2	
Shale, drab.....	6		
Total coal.....	7	4	

A bed of cannel coal has recently been found in the valley of North Fork of Virgin River, and in the fall of 1907 a prospect, known as the Cannel King (No. 12), was opened in sec. 26, T. 39 S., R. 9 W., where the following section was measured:

Section of coal bed in Cannel King prospect.

Shale, carbonaceous, fossiliferous.		Ft.	in.
Coal, bituminous.....	2	5	
Coal, cannel.....	5	6	
Shale, drab.			
Total coal.....	7	11	

The cannel-coal bed occurs about 100 feet above the conglomerate at the base of the Cretaceous section, and 160 feet below a prominent bed of white sandstone which will serve as a guide in prospecting. As yet little work has been done here and the extent of the bed has not been determined. It has not been discovered in sections made several miles northwest and southeast of the Cannel King property, and it is probable that this coal is not of great extent.

In Orderville Gulch, north of Clear Creek Mountain, the following section was measured:

Section of coal beds in Orderville Gulch.

Shale, carbonaceous.....	2	3	
Coal, bituminous.....	5	4	
Shale, carbonaceous.....	1	3	
Coal, bituminous.....	4	7	
Shale and sandstone.....	250		
Coal, bituminous.....	2	2	
Coal, cannel.....	5	6	
Shale, carbonaceous.			
Total coal.....	17	7	

In Long Valley, at the east end of the Colob field, several openings have been made on the coal, which is conveniently located and easy of access. But the quality is inferior to that of the coal farther

northwest, and locally the bed is disturbed by faults. The following sections were measured in this vicinity:

Section of coal-bearing rocks 2 miles southwest of Orderville.

	Ft.	in.
Shale, drab, fossiliferous.		
Coal and bone.....	5	
Shale, drab.....	2	
Coal.....	2	6
Shale, carbonaceous.....	5	
Sandstone, thin bedded.....	5	
Sandstone, massive.....	21	
Concealed (probably shale).....	17	
Shale, carbonaceous.....	10	
Coal.....	1	3
Concealed (probably shale).....	11	
Sandstone, massive.....	27	
Concealed (probably shale).....	60	
Sandstone, white.....	50	
Shale, drab.....	11	
Coal and bone.....	10	
Shale, carbonaceous.....	5	
Clay.....	7	
Sandstone, massive.....	37	
Conglomerate, pebbles of quartzite and limestone (base of Cretaceous).....	15	
Total coal and bone.....	18	9

At the Muddy prospect (No. 13), in sec. 7, T. 41 S., R. 7 W., a mile northwest of Mount Carmel, the following section was measured:

Section of coal bed at Muddy prospect.

	Ft.	in.
Sandstone.....	1	
Coal.....	2	2
Bone.....		7
Coal.....		7
Bone.....		2
Coal.....	3	5
Clay.....		2
Coal.....	1	5
Bone.....		7
Coal.....	1	11
Clay.....		3
Coal.....		10
Shale, carbonaceous.		
Total coal.....	10	4

At the Kroft mine (No. 14), in sec. 16, T. 41 S., R. 7 W., 2 miles south of Orderville, the following measurements were made:

Section of coal bed in Kroft mine.

	Ft.	in.
Shale, sandy, carbonaceous.		
Coal.....	4	2
Parting.....		4
Coal.....	3	4
Parting.....		$\frac{1}{2}$
Coal.....	1	8
Shale.		
Total coal.....	9	2

In the vicinity of Glendale coal occurs in the upper part of the rocks of Colorado age, and prospects have been opened northeast and southeast of the town, adjacent to the Sevier fault.

C. Levanger has opened a prospect (No. 15), in sec. 26, T. 40 S., R. 7 W., in which the following section was measured, the base of the coal not being exposed:

Section of coal bed in sec. 26, T. 40 S., R. 7 W.

	Ft.	in.
Shale.		
Coal.....	2	2
Bone.....		3
Coal.....	4	1
Total coal and bone.....	6	6

In the Glendale mine (No. 16), in sec. 24, T. 40 S., R. 7 W., one-half mile northeast of Glendale, the following section was measured:

Section of coal bed in Glendale mine.

	Ft.	in.
Shale, fossiliferous.		
Coal.....	3	2
Bone.....		3
Coal.....	4	
Shale, carbonaceous.		
Total coal.....	7	2

QUALITY OF THE COAL.

The Colob coals are deep black and have a shiny luster. They are slick and do not soil the hands like better grades of bituminous coal. Their fracture generally is irregular, with a tendency to split along bedding planes. Some of the coals have two well-developed planes of fracture at right angles, but fine prismatic cleavage is notably absent.

The composition of several samples of coal from the Colob field is shown in the following table. The samples were taken from the working faces of the mines and prospects and represent as fresh coal

as could be obtained, but as the working faces are not far from the outcrop, and as active mining was not in progress when the samples were collected, they probably represent slightly weathered coal.

Analyses of coal samples from the Colob field, southern Utah.

Location.....	NW. $\frac{1}{4}$ sec. 36, T. 36 S., R. 10 W.	NW. $\frac{1}{4}$ sec. 31, T. 36 S., R. 10 W.	NW. $\frac{1}{4}$ sec. 24, T. 37 S., R. 11 W.	NW. $\frac{1}{4}$ sec. 33, T. 37 S., R. 11 W.	NW. $\frac{1}{4}$ sec. 16, T. 41 S., R. 7 W.	NW. $\frac{1}{4}$ sec. 24, T. 40 S., R. 7 W.	NE. $\frac{1}{4}$ sec. 26, T. 39 S., R. 9 W.	
Laboratory No.....	5304	5494	5305	5307	5314	5341	a 5306	b 5308
Sample as received:								
Prox. Moisture.....	10.35	4.93	14.19	12.56	16.59	20.56	15.74	7.35
Volatile matter.....	36.33	37.24	33.39	36.43	32.59	32.43	41.92	46.93
Fixed carbon.....	43.70	44.79	42.50	46.21	37.38	40.79	28.00	22.48
Ash.....	9.62	13.04	9.92	4.80	13.44	6.22	14.34	23.24
Sulphur.....	5.82	6.72	5.39	5.24	3.41	1.19	1.32	1.61
Hydrogen.....	5.13	5.11	5.20	5.67	5.39	6.08	6.11	6.18
Carbon.....	61.24	63.01	55.27	62.13	46.66	57.11	51.96	51.88
Nitrogen.....	.95	.93	.85	.93	.85	1.01	1.16	1.06
Oxygen.....	17.24	11.19	23.37	21.23	30.25	28.39	25.11	16.03
Calories.....	6,041	6,340	5,515	6,079	4,379	5,441	5,282	5,753
British thermal units.....	10,874	11,412	9,927	10,942	7,882	9,794	9,508	10,355
Loss of moisture on air drying	1.80	1.40	2.80	1.60	3.90	4.70	4.50	1.10
Air-dried sample:								
Prox. Moisture.....	8.71	3.58	11.72	11.14	13.20	16.64	11.77	6.32
Volatile matter.....	37.00	37.78	34.35	37.02	33.91	34.03	43.89	47.45
Fixed carbon.....	44.50	45.42	43.72	46.96	38.90	42.80	29.32	22.73
Ash.....	9.80	13.22	10.21	4.88	13.99	6.53	15.02	23.50
Sulphur.....	5.93	6.82	5.55	5.32	3.55	1.25	1.38	1.63
Hydrogen.....	5.02	5.02	5.03	5.58	5.16	5.83	5.87	6.13
Carbon.....	62.35	63.91	56.86	63.14	48.55	59.93	54.41	52.46
Nitrogen.....	.97	.94	.87	.94	.88	1.06	1.21	1.07
Oxygen.....	15.93	10.09	21.48	20.14	27.87	25.40	22.11	15.21
Calories.....	6,152	6,430	5,674	6,178	4,557	5,709	5,531	5,817
British thermal units.....	11,073	11,574	10,213	11,120	8,202	10,277	9,956	10,470

a Upper 2 feet.

b Lower 3½ feet.

1

The coal contains considerable moisture, and in general a large amount of ash, though in some samples the ash is only medium; sulphur, too, is high, especially for coals of the Rocky Mountain region. The analyses show that in addition to carrying these impurities the coals are intrinsically of medium low grade, the change from the original vegetable matter from which the coal is derived having progressed only moderately in the process of transformation to pure carbon. Calculated on an ash-free and moisture-free basis, the carbon in the ultimate analyses ranges from 66 to 76 per cent. The carbon-hydrogen ratios of the air-dried samples, ranging from 12.42 to 9.40, and the heating values, which range from 8,202 to 11,120 British thermal units, also indicate that the coal is of medium to low grade. It should be noted that the samples from the western part of the field, east of Cedar City and Kanarraville, show better results than those from the eastern part, in the vicinity of Mount Carmel and Glendale. Judged from the analyses, therefore, the coal of the Colob field ranges from low-grade bituminous to subbituminous.

In view of its possible future use in reducing the iron ores in the Iron Springs district, which is only 10 miles northwest of Cedar City, the

coking quality of this coal is an important consideration. The iron ore is still undeveloped, but so far as known it is the largest deposit west of Mississippi River, and sooner or later it will be mined. Unfortunately, no satisfactory coking tests have been made of the southern Utah coal, although it is reported that a number of years ago an inferior quality of coke was produced in the Coal Creek valley. Laboratory tests in a small crucible show that the Colob coals fuse to a slightly coherent mass in which grains of coal are distinctly visible, but only tests on a practical scale can determine whether commercial coke can be made from the southern Utah coal. The high sulphur content of the Colob coal renders it an undesirable metallurgical fuel.

The cannel coal is massive bedded, of a brownish-black color, and has a dull greasy luster. Its fracture is conchoidal and the coal also tends to break along bedding planes, although it is notably tough compared with the other coals. The analyses clearly show that the coal found in the valley of North Fork of Virgin River possesses the peculiar properties of cannel. The volatile matter is high, from one and one-half times to twice as great as the fixed carbon; and the hydrogen in the analyses of dry coal is more than 5 per cent, being practically double that in the other coal beds of the Colob Plateau. The characteristic peculiarity of cannel is due to the fact that its original ingredients are largely different from those composing most coals. Thin sections of this cannel coal have been examined by David White, of the United States Geological Survey, who reports as follows:

The fuel contains very little in the way of vestiges of the cell structures of higher plants, being made up largely of russet and lemon-yellow, more or less lenticular, or globular, translucent bodies embedded in a brownish-black groundmass of somewhat flocculent aspect. Some of this translucent matter is probably resinous, while it is possible that some of the lemon-yellow substance, less in quantity, may be gelatinous, though that is not at all certain. On the whole, the microscopical composition of the coal is essentially that of a high-grade cannel.

The heating value of the cannel coal is low, 9,956 British thermal units in one specimen and 10,470 in the other, figured on an air-dried basis. These low figures, however, are largely due to the considerable amount of ash in the coals. The high content of volatile constituents makes cannel coal a valuable gas producer.

KANAB FIELD.

LOCATION.

The Kanab coal field is the eastern continuation of the Colob field, and is named from Kanab Creek. This field is bounded by the Sevier fault on the west, and extends northeastward toward Paria River, the present work ending at range 5 of the Land Office survey. The coal in the Kanab field in general is more accessible than in the Colob field; a number of roads cross the area, and the outcrop of the coal

measures in most places is easily reached. But, on the other hand, this field is far distant from an immediately prospective market of any consequence.

OCCURRENCE AND THICKNESS OF COAL.

In the Kanab as in the Colob field, coal occurs in the lower part of the Cretaceous section, and the same buff sandstone-shale series, within a hundred feet or so above the basal Cretaceous conglomerate which overlies the Jurassic varicolored shale and gypsum, can be used as a guide in prospecting. In addition to the lower coal, another bed 4 feet 5 inches thick occurs several hundred feet higher, on which a prospect pit (No. 17) has been opened about 3 miles southwest of Upper Kanab.

The main coal horizon in many places can be easily traced by the dark streak caused by the outcrop along the hillsides, but very little prospecting has been done. Two openings have been made on the coal in the valley of Kanab Creek, about 5 miles south of Upper Kanab. At the old Siler prospect (No. 19), in sec. 25, T. 39 S., R. 6 W., the drift had caved in, but in the Johnson prospect (No. 18), about one-half mile to the northwest, the following section was measured:

Section of coal beds in Johnson prospect (No. 18).

Shale, drab.	Ft.	in.
Coal.....	1	6
Bone.....		3
Coal.....	1	
Bone.....		1
Coal.....		7
Limestone.....		3
Coal.....	3	11
Shale, carbonaceous.		
Total coal.....	7	

No other test pits were found in the Kanab field within the area studied in 1907. Apparently the coal thins out east of Kanab Creek, and there is an area of barren rocks that extends an indefinite distance beyond the limits of the region mapped (Pl. XXV), in which coal of workable thickness has not been found. The following section, measured near the east end of the area studied, shows the greatest thickness of coal found in that vicinity:

Section of coal beds in the NW. $\frac{1}{4}$ sec. 35, T. 40 S., R. 5 W.

Shale, carbonaceous.	Ft.	in.
Coal and bone.....	1	9
Shale, carbonaceous.....		3
Coal.....	1	6
Shale, carbonaceous.....	2	3
Total coal and bone.....	3	3

QUALITY OF THE COAL.

Fresh samples from the Kanab field could not be obtained, and no analyses have been made of this coal. It resembles that from the eastern part of the Colob field, of which it is a continuation, and probably the analyses of the coal from Tps. 40 and 41 S., R. 7 W., indicate the general composition of the coal in the Kanab field. It should be noted, however, that the cover of the coal in a considerable part of the field, for 2 or 3 miles back from the outcrop, is generally slight—in many places less than 100 feet—and doubtless in such places, on account of weathering, the coal is of inferior quality.

THE ROGUE RIVER VALLEY COAL FIELD, OREGON.

By J. S. DILLER.

LOCATION.

Coal occurs at numerous localities in the Rogue River valley of southwestern Oregon, between the Cascade Mountains on the east

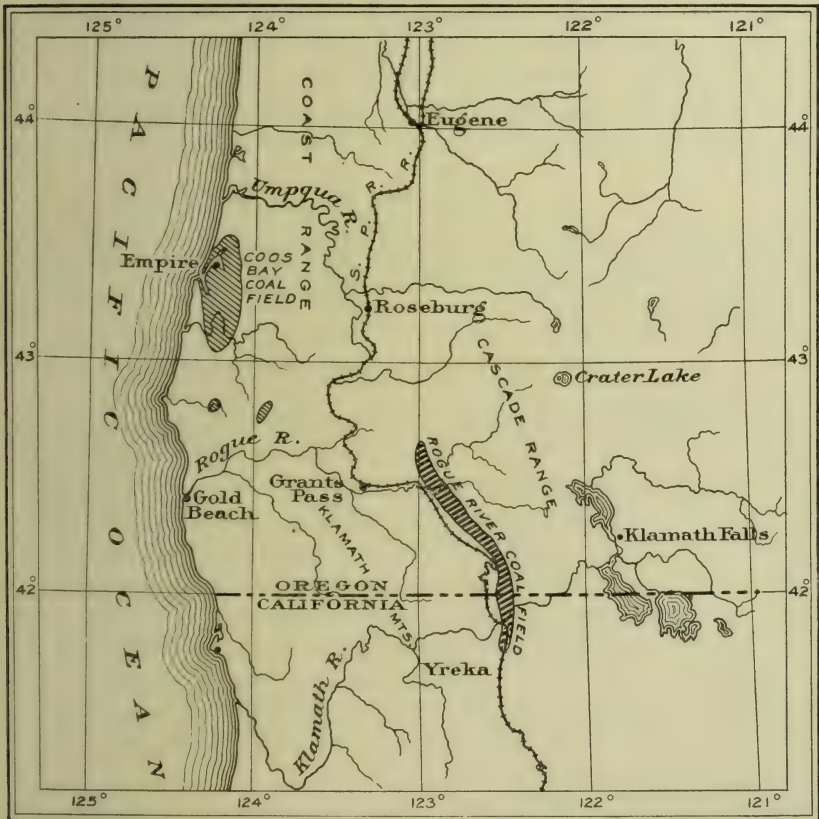


FIG. 6.—Map of Rogue River valley and other coal fields of southwestern Oregon.

and the Klamath Mountains, locally called the Siskiyou Mountains, on the west. The long, narrow coal belt, as outlined in fig. 6, begins

at the north on Evans Creek in T. 33 S., R. 2. W. of the Willamette principal meridian, stretches to the south and southeast in the Rogue River Valley east of Medford and Ashland, and continues through the Siskiyou Mountain divide into California, a total distance of nearly 100 miles.

STRUCTURE OF COAL BELT.

The Cascade Range, east of the coal belt, is made up mainly of Tertiary lavas; the Klamath Mountains, on the west, are composed of granular igneous rocks and a smaller proportion of pre-Cretaceous sediments.

The soft rocks in which the Rogue River valley has been cut are sandstones, shales, and conglomerates. They dip generally eastward, extending beneath the greater portion of the lava fields of the Cascade Range. The older sediments along the western border of the valley, by Bear Creek from the Toll House to Ashland, Phoenix, and Jacksonville, are Cretaceous in age and do not contain coal. The coal-bearing rocks lie east of Bear Creek as far north as Medford, but beyond that point they overlap the Cretaceous rocks and occupy the whole northern portion of the Rogue River valley.

THE COAL.

The principal prospects have been made near Medford and Ashland, but others occur on Evans Creek, to the north, and near Ager, in California, to the south.

PROSPECTS ON EVANS CREEK.

On Evans Creek the strata dip locally to the northwest, but at the time of examination the incline by which the coal was prospected was full of water, so that the available exposures were unsatisfactory. However, there appear to be 8 feet, if not more, of coal, some of which is of fair quality, but most of which is impure and shaly. The coal bed has, besides a number of small clay partings, two prominent partings of sandstone, one 12 inches and the other 6 inches thick. The shaly coal has been sheared so that much of it is slickensided and goes to pieces on exposure. The immediate vicinity does not show a large body of coal above drainage level. The coal at this point appears to lie within a few hundred feet of the base of the coal-bearing rocks.

Coal is reported from the meadows on Evans Creek and also from Table Mountain on Rogue River, but as there was no active prospecting at either locality they were not specially examined.

COAL NEAR MEDFORD.

The coal 6 miles east of Medford lies along the foot of the steeper slope, which rises from the edge of the valley, 600 feet above the town, to the bold front of the Cascade Range. Some years ago the Southern Pacific Company prospected a coal bed at this point, and the size of the dump indicates that the trial drift must have been about 100 feet in length. Since then R. P. Little has discovered a number of other coal beds a short distance farther up on the same hillside and opened two of them by slopes, tunnels, and drifts aggregating nearly 900 feet in length. Drainage is effected by a lateral tunnel into an adjacent ravine. Considerable coal has been hauled to Medford and sold at \$8 per ton.

The principal bed prospected is about 12 feet thick, and the striking feature at the entrance of the gentle slope is the large number of clay and sand partings with very little coal between them. The partings weathering whitish are strongly contrasted with the darker bands. As the slope is descended along the bed there appears a decided increase in the quantity and improvement in the quality of the coal toward the northeast. The bands of black lustrous coal, generally not over 6 to 8 inches thick, locally swell to more than a foot and furnish the source of supply for the local demand. The intermediate shaly coal and coaly shale is abundant and requires much picking to obtain satisfactory results. Several faults striking N. 40° E. and dipping 26° to 42° SE. have been encountered in the tunnels. The direction of movement and the amount of displacement could not be definitely determined. No lavas were seen in the mine, but they appear higher up, overlying the whole succession of coal beds. The decided improvement in the coal down the dip suggested that as the most favorable direction in which to prospect.

Since the examination on which the foregoing statement is based was made the Pacific Coal Company has purchased this mine and has developed the openings to the northeast along the dip of the coal bed for more than 1,000 feet. The prediction that the coal would be found of better quality and in larger quantity has been confirmed. A few small faults have been encountered, but these are all of the normal type and easily overcome. The mine is now producing coal and supplies the local market. The development of this mine has greatly stimulated prospecting in other parts of the field.

J. A. Holmes, of the Geological Survey, collected a sample of coal at this locality last summer and has kindly furnished the following results of an analysis made in the laboratory of the Survey fuel-testing plant:

Analysis of sample of coal obtained near Medford, Oreg.

[F. M. Stanton, chemist in charge.]

	As received.	Air dried.
Laboratory No.....	5346.	5346.
Loss of moisture on air drying.....		2.00
Moisture.....	11.30	9.49
Volatile matter.....	23.39	23.87
Fixed carbon.....	31.89	32.54
Ash.....	33.42	34.10
Sulphur.....	1.16	1.18
Calories.....	4,183	4,268
British thermal units.....	7,529	7,683

The sample taken is a complete section of the coal bed exposed and represents what has to be removed in working the coal. It contains not only the good coal, but all the shaly partings. The high percentage of ash indicates that the bed contains much that would have to be thrown away in mining. The ash is about four times as great as that of the bed mined at Libby, in the Coos Bay region.

In prospecting the region systematically the entire coal-bearing series should be drilled from top to bottom to determine the number, position, and relative value of the beds, and then they should be worked at the top first. If the lower beds are worked out first, those next above may be rendered unworkable by caving and thus lost.

It is not to be expected that the coal beds extend to a very great distance beneath the Cascade Range before being disturbed by the rising lavas of the range, but it may well be that they continue far enough to give a considerable body of coal of various grades that will supply for the present, in some measure, local demands for fuel and that will in the future, when producers and gas engines are perfected, furnish an important source of power.

Several other prospects have been opened to the north and also to the south of those of Mr. Little, but nowhere are the works extensive enough to show continuity of the beds.

COAL NEAR ASHLAND.

Four miles north of Ashland several coal beds have been faced up in short slopes by D. P. Greninger. A striking feature of this coal, as of that near Medford, is the decided increase in the amount and improvement in the quality of the coal to the northeast, but the workings are not extensive enough to afford a fair opportunity of estimating their value. Neither lavas nor faults were encountered here. The beds are not so large as those farther north. They have furnished a few tons of coal for the local market.

Greater activity is shown 4 miles east of Ashland, near the "Gillett Lithia Springs," where the Ashland Coal Company has run slopes into two coal beds, the upper 12 feet and the lower 5½ feet thick, sepa-

rated by 50 feet of slippery shale and shaly sandstone. The coal beds are made up of streaks of good coal locally 6 inches thick and separated by coaly shale. The coal breaks out in blocks and contains a considerable percentage of sulphur. The disturbing features at this prospect are irregular masses of old lavas, which appear not only in all the entries, but at various levels on the surface and in bluffs near by along the creek. Where the coal is in contact with the lava the latter appears to be the older. The abundance and irregularity of these lava masses render the extent of the coal beds a matter of doubt.

COAL NEAR AGER, CAL.

As already stated, the coal belt extends south through the Siskiyou Mountains into California, where several coal beds have been reported near Ager and one of them prospected to a considerable depth on an incline of 45°.

SUMMARY.

Although coal beds have been prospected, as noted above, at six localities between Evans Creek and Ashland, a distance of 40 miles, the evidence thus far available does not indicate the continuity of the same coal beds throughout that distance, but rather the development of small beds a few miles in greatest extent parallel to the coal belt and to the old shore line along which the vegetation accumulated in swamps to form coal. The swamps lay at the base of the Klamath Mountains when the coal-bearing beds were deposited over the low flats and the shallow body of water extending to the northeast.

The most impressive feature at all the localities examined is the improvement in the coal toward the northeast, down the dip of the coal beds into the hill. This is not simply a matter of weathering, but a decided increase in the amount of coal present and a decrease in the amount of fine sediment washed into the original swamp where the vegetal matter was accumulating. The farther northeast in the swamp the deposits lie, the farther from the source of the wash from the slopes of the Klamath Mountains and to a certain extent the thicker and purer the coal.

The age of the coal-bearing rocks of the Rogue River valley is not yet fully determined. They contain numerous fossil leaves which are now regarded by Doctor Knowlton as Eocene, although the latest collections from that region have not yet been studied. It is probable, however, that they are Eocene and of approximately the same age as the coal of Coos Bay.

For the present the coal beds from Ager to Evans Creek are only of local interest as a source of fuel, but detailed examinations in the future may show these coals to be more extensive than they are now supposed. If so, they may become, with the improvement of gas producers, important sources of power.

A COAL PROSPECT ON WILLOW CREEK, MORROW COUNTY, OREGON.

By W. C. MENDENHALL.

The coal prospect here described is on Willow Creek, about 22 miles above Heppner, the county seat of Morrow County, Oreg., in a rather mountainous region just west of the divide between the Willow Creek and the John Day River drainage. The coal property is in secs. 33, 34, 35, and 36, T. 4 S., R. 28 E. Willow Creek, a tributary of Columbia River, flows through a canyon from its source to its mouth, but this canyon deepens toward the head of the stream because the general level of the surrounding country is higher in this direction. The elevation of the bed of the creek in the vicinity of the coal prospect is about 4,400 or 4,500 feet above sea level. That of the highest summits near by is perhaps 7,000 feet.

The walls of the lower portion of Willow Creek canyon reveal sections of basalts exclusively. These rocks underlie the central portion of the Columbia River valley, and are probably to be correlated with the Yakima basalt of central Washington. Eighteen or 20 miles above Heppner the geology changes abruptly and older, altered rocks, including basic plutonics and granitic and diabasic intrusives, appear in the canyon walls. These rocks clearly represent a part of the basement upon which the lavas were poured out and their abrupt appearance is probably to be explained by the presence of a sharp fault of perhaps a few thousand feet throw, with the uplift on the eastern side of the fracture. Just below the coal mines coarse feldspathic sandstone outcrops, overlying the older basement rocks and dipping in general 20° or 25° SE., the strike of the sedimentary beds being northeast and southwest with local variations in attitude. This belt of sediments is reported to have been explored for 15 or 20 miles along the strike and to extend, therefore, to the southwest across the divide into the John Day drainage basin. Overlying the sedimentary beds the basalts appear again, capping the neighboring ridges. The total thickness of the sedimentary section here was not measured, but by combining the apparent exposed section above the creek bed with the

reported record of a diamond-drill hole 602 feet deep, bored in the vicinity of the prospects, the conclusion is reached that the sedimentary rocks are probably less than 2,000 feet thick. The beds exposed in the neighborhood of the coal mines are sandstones of varying degrees of coarseness, but softer shale is reported higher up on the slopes. A few poor specimens of fossil plants were collected from the roof of one of the drifts and submitted to F. H. Knowlton for determination. He reports, in part, as follows:

This material contains the following species:

Monocotyledonous plant (unknown to me).

Glyptostrobus cf. *G. europæus* Heer.

Quercus consimilis? Newberry.

Populus sp.?

I am uncertain about the age of this material, but from the presence of what appears to be *Quercus consimilis* I incline to regard it as * * * upper Clarno [upper Eocene].

The coal was discovered some years ago by Willard Herron, by following up float found in the creek bed. The property is now reported to be owned by D. A. Herron, C. A. Redfield, and George Conser jointly, and the statement is made that about \$82,000 has been expended in exploitation and development. Five drifts have been carried into the sides of the canyon. No. 1 is only a few feet long, No. 2 about 50 feet, No. 3 about 150 feet, No. 4 about 380 feet, and No. 5, known as the "Conser tunnel," 290 feet. No. 4 is in the best condition for examination at present and is the only one explored at the time of the writer's visit, November 7, 1907. It has been driven into the west side of the canyon wall in a nearly westerly direction, following the local strike. Near its entrance the drift is timbered, and near the heading, which has been chambered out into rooms 15 or 20 feet long, 10 or 12 feet wide, and 8 or 10 feet high, some props have been placed. The immediate floor and roof of the coal bed are of that variety of black, homogeneous, nonfissile, and highly carbonaceous shale usually characterized as bone. These shale bands are only a few inches thick and above and below them appears the sandstone which makes up the major part of the inclosing formation. The sandstones, both above and below the coal, are rolling and irregular, so that the thickness of the coal is variable. The coal bed where measured is about 53 inches thick and consists of an intimate interbedding of bands and lenses of pure coal, apparently bituminous in its nature, with bands of bone similar to that forming the roof and floor. These materials are interbedded in such thin bands as to make it difficult to separate the coal from the bone commercially. Selected pieces of coal can be taken which would yield a low percentage of ash and would probably give high-grade tests, but such sampling would not yield practical results.

So far as known all the drifts are on one coal bed, but the 602-foot diamond-drill hole bored in the creek bed opposite the mouth of one of these drifts and starting perhaps 25 or 30 feet below its level is reported to have passed through six beds of coal. The thicknesses of the upper two, whose positions are not given in the section, are reported at 8 feet 4 inches and 7 feet 6 inches; the other four are very much thinner. No accurate idea could be gained of the quality of the coals passed through by the drill. No effort has been made thus far to sink shafts to these beds, so that it may be assumed that their quality was not sufficiently good to justify this expenditure.

The owners of the prospects report that selected samples of the coal have yielded from 51 to 71 per cent of fixed carbon by analysis; that the average moisture content is about 8 per cent, and that samples yielding as low as 5 per cent of ash have been analyzed. It is stated that a fair sample across the face of one of the drifts has yielded about 26 per cent of commercial coal, and that in other places the coal forms from 12 to 40 per cent of the total thickness of the bed.

It will be evident from the above account that the coals thus far revealed by developments are not usable in the ordinary commercial way because of their very high percentage of ash, due to the intimate intermingling of coal and bone. It is possible, however, that as they occur in a region remote from other sources of hydrocarbon fuels, they may prove to be suitable for use in producer-gas engines, when this means of developing power has become more general.

THE POCKET COAL DISTRICT, VIRGINIA, IN THE LITTLE BLACK MOUNTAIN COAL FIELD.

By CASSIUS A. FISHER.

INTRODUCTION.

During the early part of June, 1908, the writer made a brief examination of the coal deposits in the vicinity of Pennington Gap, Virginia. Considerable exploitation and development work has been done in this district during the last three years, and as a result a large amount of valuable information concerning the stratigraphic position and distribution of the various workable coal beds has been obtained. This information, which was kindly furnished by the persons interested, together with additional data collected during a brief examination of the area, is regarded as sufficient to warrant the present publication.

LOCATION AND EXTENT.

The Pocket coal district is located in Lee County, in the southwest corner of Virginia, between Cumberland and Little Black mountains, mainly on the southern slope of the latter. It constitutes a part of the Black Mountain coal field, which extends along the northwestern side of Cumberland Mountain throughout southwestern Virginia into eastern Kentucky. The name "Pocket" has been applied to this district owing to the fact that it is a topographic depression surrounded on three sides by high ridges. It is about 9 miles long and 4 to 5 miles wide, comprising about 40 square miles. It lies just north of Pennington Gap, Virginia, and is reached by a branch of the Louisville and Nashville Railroad from Pennington station and also by a branch of the Southern Railway from Appalachia. Above the junction at the upper end of the gap a line extends up Straight Creek, from which branches have been built up Baley Trace, Fawn Branch, and Gin Creek to the various coal mines. These lines are used jointly by the two railroad systems, and they extend to all the operations in the district. (See fig. 7.)

TOPOGRAPHY.

The district is one of hilly topography, with very little level land, being made up mainly of steep-sided, narrow-topped, irregular ridges that rise to the northwest, culminating in Little Black Mountain, which has an altitude of about 3,500 feet.^a This ridge marks the State boundary line between Kentucky and Virginia. Along the southern border of the district Stone Mountain extends as a high, narrow ridge,



FIG. 7.—Sketch map of the Pocket coal district, Virginia, in the Little Black Mountain coal field.

rising about 1,200 feet above the river at Pennington Gap. The district is heavily wooded and thinly populated except along the narrow stream valleys.

DRAINAGE.

The principal stream of the district is Straight Creek, which rises high on the slope of Little Black Mountain and, flowing southward, empties into North Fork of Powell River, at the head of Pennington

^aThis altitude was taken from a reconnaissance topographic map which can be regarded only as approximate.

Gap. Its principal tributaries are Gin Creek, Baley Trace, Puckell Creek, and Stone Creek, all entering from the west. Fawn Branch and Ely Creek, tributaries of Baley Trace and Stone Creek, respectively, also drain small areas in the western part of the district. These are all vigorous mountain streams, carrying considerable water except in very dry seasons.

STRUCTURE.

The structure of the rocks in the Pocket coal district is comparatively simple. Throughout the greater part of the area the beds lie nearly horizontal, dipping gently northwestward. Along the base of Stone Mountain, however, they are sharply upturned, and this mountain is composed of vertical strata which produce sharp, knife-blade ridges. It is possible that the beds are more or less faulted along the northern side of Stone Mountain, where their dips change from a low angle to vertical within less than one-fourth of a mile. No definite evidence of a fault along this line, however, was observed in the field. Throughout the central part of the district, where the rocks are nearly horizontal, no faults were observed or reported.

GEOLOGIC OCCURRENCE OF COAL.

The rocks of the Pocket coal district all belong to the Pottsville group, of Pennsylvanian age. They have an estimated thickness of about 4,000 feet. The beds constituting the lower half of the section have not been subdivided into formations in this district. They consist mainly of sandstone and shale with many beds of coal distributed throughout. The beds of workable thickness, however, are confined largely to the upper half of the section.

During the present investigation information was obtained from representatives of the Black Mountain Coal Land Company, the principal owner of this part of the Little Black Mountain coal field, concerning the relative position of all the important workable coal beds with respect to a gray, coarse-grained sandstone occurring near the summit of Little Black Mountain, which is said to be the Harlan sandstone. This information, together with observations on the quality of the coal of the different beds, is here set forth.

There are twelve known workable coal beds in this district and two which may possibly be workable. They have a combined thickness of about 54 feet, and occur within a stratigraphic interval of about 2,090 feet. These beds are designated by numbers ranging from 1 to 12. Bed 1, the lowest in the series, occurs about 2,090 feet below the so-called Harlan sandstone, and bed 12, the highest, immediately beneath it. A generalized section, omitting all details and showing

the relative positions of the various workable coal beds of this district, is given below:

Generalized section showing positions of coal beds in the Pocket district, Virginia.

	Feet.
Harlan sandstone (?), exposed.....	40
Coal bed 12.....	4½
Interval.....	60
Coal bed 11.....	3
Interval.....	300
Coal bed 10.....	6
Interval.....	40
Coal bed 9.....	4½
Interval.....	100
Coal bed 8.....	4
Interval.....	100
Coal, impure.....	4
Interval.....	100
Coal bed 7.....	3½
Interval.....	325
Coal bed 6.....	4½
Interval.....	275
Coal bed 5.....	3½
Interval.....	180
Coal bed 4.....	2½
Interval.....	180
Coal bed 3.....	3½
Interval.....	40
Coal bed 2 A.....	3
Interval.....	40
Coal bed 2.....	3
Interval.....	300
Coal bed 1.....	4½
	2, 134

DETAILED DESCRIPTION OF COAL BEDS.

General statement.—Only the coal beds of commercial importance occurring in the upper half of the Pottsville group were studied. A number of coal beds lower in the Pottsville, and also in the basal formation of that group, the Lee conglomerate, have been mined at country banks for years, but these are thin and they were not examined. According to reports, there are five or six of these beds, ranging in thickness from 2 to 3 feet.

The following notes give in ascending order a brief description of the stratigraphic position, thickness, and general characteristics of each of the more important workable coal beds in the Pocket coal district.

Bed 1.—About 2,090 feet below the base of what is believed to be the Harlan sandstone occurs a coal bed which is known locally as

bed 1. This bed is said to range in thickness from $3\frac{1}{2}$ to 6 feet, with an average of $4\frac{1}{2}$ feet, and it is generally free from partings. It usually has a sandstone roof and floor, although in some localities a "draw slate" is present between the coal and overlying sandstone, which attains a maximum thickness of 7 feet. As this is the lowest workable bed in the series, it has a wider distribution than any other coal bed in the district. It outcrops in the bluffs on either side of Straight Creek, a short distance above its mouth, and is carried by the dips beneath the level of that stream some distance below Black Mountain station.

Bed 2.—About 300 feet above bed 1 is bed 2, which averages 3 feet in thickness. It is overlain by sandstone and underlain by shale and contains no partings of appreciable thickness. This coal bed outcrops on the west bank of Straight Creek, about one-fourth mile below Black Mountain station, where it passes beneath the level of the creek.

Bed 2 A.—Forty feet higher stratigraphically than bed 2 is another somewhat thicker coal bed, which has been designated bed 2 A. In some localities this coal bed is said to reach a thickness of 6 feet, but its normal thickness is about 3 feet. The bed generally consists of clean coal without partings, and has a sandstone roof and shale floor. It has been mined slightly at a country bank on the west side of Straight Creek, at Black Mountain station, where it occurs about 10 feet above the level of the valley.

Bed 3.—This coal bed occurs about 40 feet above coal bed 2 A, and has a thickness of 3 feet 2 inches at the Virginia Lee Company's mine, one-fourth mile above Black Mountain station, on the west side of Baley Trace, where the bed is now worked. This thickness is slightly below the average. A 2-inch parting occurs about 1 foot above the base, and the coal is overlain by drab shale, which is said to afford an exceptionally strong roof. The floor is of clay. Bed 3 passes beneath the level of Baley Trace near the mouth of Fawn Branch.

Bed 4.—At about 180 feet above bed 3 is bed 4, which has a thickness of about $2\frac{1}{2}$ feet. This attains workable thickness at a few places in this field. It is exposed on the west side of Baley Trace, above the mouth of Fawn Branch.

Bed 5.—This coal bed occurs about 180 feet above No. 4. It ranges in thickness from 3 to 4 feet and is clean and free from partings. It is overlain by sandstone and underlain by clay. At the head of Fawn Branch, where this bed is being opened at many places, a measurement of one of the beds opened by the Virginia Lee Company gives a thickness of 3 feet 7 inches, with no appreciable parting. Bed 5 is opened and mined at many places along Fawn Branch, Baley

Trace, Straight Creek, and Gin Creek, and is regarded by operators as one of the most valuable coal beds in the district. It is mined at Darbyville and consequently is known to some extent as the Darby bed. It is said to be the stratigraphic equivalent of the Taggart coal of the Big Stone Gap region.

Bed 6.—About 275 feet above bed 5 is bed 6, which at the head of Straight Creek, at the Virginia Iron, Coal and Coke Company's mine, has a thickness of 4 feet 4 inches, with a $\frac{1}{2}$ -inch parting 14 inches above the base. It is overlain by shale and underlain by clay. This coal was examined at the head of Straight Creek, where it outcrops at an elevation between 1,600 and 1,700 feet.

Bed 7.—Between beds 6 and 7 there is a stratigraphic interval of 325 feet. Coal bed 7 has an average thickness of $3\frac{1}{2}$ feet, and is separated near the middle by a clay parting. It has a shale roof and floor. This coal outcrops relatively high in the slope of Little Black Mountain, and consequently has a smaller areal distribution than any of the beds described above. A section of this coal bed, measured in an opening on the left fork of Gin Creek, is as follows:

Section of coal bed 7 on left fork of Gin Creek.

	Ft. in.	
Shale, exposed.....	5	
Coal.....	2	5
Clay, light gray.....		7
Coal.....	1	9
Shale.....		
Total coal.....	4	2

Bed 8.—About 200 feet above No. 7 occurs bed 8, which has a thickness of 4 feet. This bed was not examined. It occurs some distance up the slopes of Little Black Mountain, and consequently has a relatively limited distribution in the district, underlying only the higher portions of the mountain. At a horizon halfway between Nos. 7 and 8 there is a coal bed which attains workable dimensions in some places, but the bed as a whole contains so large a percentage of shale that it can not be worked.

Bed 9.—This bed occupies a position about 100 feet above No. 8. It has a thickness of nearly 5 feet and in some localities it contains a thin parting in the lower half. It has been opened at many places along the southern slope of Little Black Mountain, but is reported not to have been mined anywhere within the district. It was examined by the writer at the heads of Baley Trace and Gin Creek. The sections of the bed at these two openings, which are about $1\frac{1}{2}$ miles apart, are very similar. The coal is overlain and underlain by shale. A section of the bed at the opening on Baley Trace is given on the next page.

Section of coal bed 9 at Wax opening, at the head of Baley Trace.

	Ft.	in.
Shale, sandy.....		
Coal.....	3	6
Shale, carbonaceous.....		1½
Coal.....	1	1
Coal, impure.....		4
Total coal.....	4	11

Bed 10.—About 40 feet above bed 9 occurs bed 10, which is one of the thickest coal beds in the district. It has an average thickness of 6 feet, and contains a clay parting in the upper part, also a thin coaly shale layer about 2 feet above the base. The bed is usually overlain by sandstone and underlain by shale. It outcrops high in the slopes of Little Black Mountain, and covers but a small area within the district. Three sections of bed 10 were measured, two at the head of Baley Trace and one on the left fork of Gin Creek. The following sections are representative of the bed:

Section of coal bed 10 at the head of Baley Trace.

	Ft.	in.
Sandstone, gray.....	8	
Coal.....	1	7
Shale, coaly.....		1½
Coal.....		3½
Clay, light gray.....		8
Coal.....	2	6
Shale, coaly.....		1½
Coal.....	2	6
Total coal.....	6	10½

Section of coal bed 10 at the head of Gin Creek.

	Ft.	in.
Coal.....	1	
Clay.....		4
Coal.....	2	8
Shale, coaly.....		1
Coal.....	2	1
Total coal.....	5	9

Bed 11.—About 300 feet above bed 10 occurs bed 11. This coal bed was not examined, but it is reported to be 3 feet thick. It outcrops high on the mountain slope, being only 70 feet below the base of the Harlan sandstone, and underlies only the upper portion of Little Black Mountain.

Bed 12.—This is the highest workable bed known in the district. It occurs 60 feet above bed 11, immediately beneath a massive gray coarse-grained sandstone believed to be the Harlan sandstone. The bed has a thickness of 4 to 5 feet and consists of firm, massive coal. As it is the highest coal bed on the slopes of Little Black Mountain, it has the smallest distribution of all the beds within the district. It

has been opened at a number of places, but, like all beds above No. 6, it has not been mined in the Pocket district. A section of this bed is given below:

Section of bed 12 at the head of the left fork of Gin Creek.

	Ft.	in.
Sandstone (Harlan?).		
Coal.....		6
Shale, carbonaceous.....		4½
Coal.....	4	
Clay.		
Total coal.....	4	6

CHARACTER OF COAL.

PHYSICAL PROPERTIES.

During the examination of the coal of this district special attention was given to a study of the physical properties, and a number of samples were collected for comparative study. The result of a systematic study shows that the coals of the different horizons, 14 in number, do not differ widely in physical properties, but, on the other hand, bear a regional resemblance to each other. Certain exceptions were noted, however, which will be described.

The coals of this district are usually of a pitch-black color, with a dark-brown streak and brown to black powder. They have a subdued vitreous luster, owing to the fact that they are composed of indistinct bands of bright and dull coal. The coal has a distinctly bedded structure, which on close examination is found to be laminated. It has cubic jointing or cleavage, the major joints occurring at intervals of about 4 inches and the minor at one-half inch. The coal breaks with an irregular fracture and is moderately brittle, although in some beds in the district it is tough. In no place was the coal observed to be crumbly. It has a metallic impact and is moderately heavy. The coal burns with a long, yellow flame, emitting a bituminous odor. In burning it leaves a relatively small amount of ash, which is reddish-yellow in color and moderately fine. There is very little sulphur or resin in the coal, but mineral charcoal is fairly abundant. These general statements concerning the physical properties of the coals of this district do not wholly apply to beds 7 and 12. The former contains coal which, although bedded, is decidedly more massive than the average coal of the district. It is also firmer and more resistant to breakage. On the whole, the coal of bed 7, from a physical point of view, is regarded by the writer as a superior variety. The coal of bed 12 is also a very firm, finely laminated coal, and in some respects resembles a splint coal. It breaks in large blocks and appears to resist weathering more successfully than some of the other coals.

CHEMICAL PROPERTIES.

In addition to the samples of coal obtained for a comparative study of physical properties, a number were collected in the uniform manner prescribed by the United States Geological Survey for chemical analysis. The result of these analyses is given in the following table:

Analyses of coal samples from the Pocket district, Virginia.^a

[F. M. Stanton, chemist in charge.]

No. of coal bed.....		5	9	10	12
Location.....		Baley Trace.	Gin Creek.	Left fork of Gin Creek.	
Laboratory No.....		6236	6238	6237	6239
Sample as received:					
Prox.	Moisture.....	3.42	4.44	5.31	5.49
	Volatile matter.....	34.36	35.99	32.66	36.03
	Fixed carbon.....	58.83	53.59	53.23	51.87
	Ash.....	3.39	5.98	8.80	6.61
Ult.	Sulphur.....	.58	.76	.75	1.24
	Hydrogen.....	5.25	5.19	5.13	5.19
	Carbon.....	77.98	71.95	70.39	71.47
	Nitrogen.....	1.29	1.25	1.36	1.12
Oxygen.....		11.51	14.87	13.57	14.37
Calories.....		7,852	7,424	7,099	7,283
British thermal units.....		14,134	13,363	12,778	13,109
Loss of moisture on air-drying.....		1.40	2.10	3.10	3.10
Air-dried sample:					
Prox.	Moisture.....	2.05	2.39	2.28	2.47
	Volatile matter.....	34.85	36.76	33.71	37.18
	Fixed carbon.....	59.66	54.74	54.93	53.53
	Ash.....	3.44	6.11	9.08	6.82
Ult.	Sulphur.....	.59	.77	.78	1.28
	Hydrogen.....	5.16	5.07	4.94	5.00
	Carbon.....	79.09	73.49	72.64	73.76
	Nitrogen.....	1.31	1.28	1.40	1.16
Oxygen.....		10.41	13.28	11.16	11.98
Calories.....		7,964	7,582	7,326	7,516
British thermal units.....		14,334	13,650	13,187	13,528
Thickness of coal bed.....			<i>Ft. in.</i> 4 10	<i>Ft. in.</i> 5 10	<i>Ft. in.</i> 4 6

^a As soon as taken these samples were placed in tightly fitting screw-top cans which were hermetically sealed six hours later.

COKING QUALITIES.

Although practical coking tests have not been made of all the coal beds in the Pocket coal district, it is believed by the writer that coke of average quality could be made from most of the workable beds. Samples of coke, apparently of excellent quality, that were seen in the field, were said to have been made of run-of-mine coal from beds 5 and 6, and also of mixed coal from these two beds. So far as could be ascertained no practical coking tests have been made of coals from other beds in the district, but the adhesion test described by Pishel^b was applied to samples of coal from beds 3, 5, 6, 7, 9, 10, and 12 with fairly satisfactory results. This process, given briefly, is as follows:

Pulverize in an agate mortar a small quantity of the coal to be tested until it will pass through a 100-mesh sieve. Pour out the pulverized coal and observe the condition of the mortar and pestle. With some coals the mortar and pestle will be deeply

^b Pishel, M. A., A practical test for coking coals: Econ. Geology, vol. 3, No. 4, June-July, 1908.

covered with a coating of coal dust, which adheres so strongly to the agate surface that it is removed with difficulty. With other coals there will be only a thin film of coal dust adhering to the mortar and pestle, while with still others both mortar and pestle will be nearly as clean after the coal is pulverized as they were before the operation began. * * * The degree of adhesion seems to coincide with the coking qualities of the coal. If it adheres strongly the coal will probably make excellent coke; if it adheres only slightly the coal possesses the coking qualities to only a slight extent, if at all; and if the mortar shows no coating of dust the coal is to be regarded as noncoking.

DEVELOPMENT.

Coal has been mined from small banks in this district for many years to supply a small local demand. The heavily forested condition of the region makes wood so cheap and easy to obtain that there was little incentive on the part of the native population to develop coal for domestic fuel. With the building of the Louisville and Nashville Railroad and other lines into this district increased interest was shown in the coal beds and considerable prospecting was done.

The following companies are operating or are preparing to operate in the near future: Virginia Lee Company, Dominion Coal Company, Black Mountain Mining Company, Lee Coal Company, Darby Coal and Coke Company, Bondurant Coal Company, Monarch Coal and Coke Company, Black Mountain Collieries Company, and Virginia Iron, Coal, and Coke Company.

CLASSIFIED LIST OF PAPERS DEALING WITH COAL, COKE,
LIGNITE, AND PEAT CONTAINED IN PUBLICATIONS OF U. S.
GEOLOGICAL SURVEY, EXCEPT THOSE ON ALASKA.^a

Compiled by WILLIS T. LEE and JOHN M. NICKLES.

This list contains the more important papers published by the United States Geological Survey dealing with coal, coke, lignite, and peat, from an economic standpoint. The page references indicate whether a paper is devoted wholly or in part to these subjects.

Papers general in scope are given first; then those dealing with restricted areas are listed in chronologic order under the States arranged alphabetically.

STATISTICAL.

The reports on coal in the volumes of Mineral Resources of the United States contain, in addition to statistical matter, various other information.* The statistics are given for the United States as a whole and for the States severally in alphabetic arrangement.

Mineral Resources of the United States. Albert Williams, jr. [For 1882-3], 1883: Coal, pp. 1-107. Calendar years 1883 and 1884, 1885: Coal, pp. 11-143; The manufacture of coke, by J. D. Weeks, pp. 144-213. Calendar year 1885, 1886: Coal, pp. 10-73; The manufacture of coke, by J. D. Weeks, pp. 74-129.

Mineral Resources of the United States. David T. Day. Calendar year 1886, 1887: Coal, by C. A. Ashburner, pp. 224-377; The manufacture of coke, by J. D. Weeks, pp. 378-438. Calendar year 1887, 1888: Coal, by C. A. Ashburner, pp. 168-382; The manufacture of coke, by J. D. Weeks, pp. 383-435. Calendar year 1888, 1890: Coal, by C. A. Ashburner, pp. 168-394; The manufacture of coke, by J. D. Weeks, pp. 395-441. Calendar years 1889 and 1890, 1892: Coal, by E. W. Parker, pp. 145-286. Calendar year 1891, 1893: Coal, by E. W. Parker, pp. 177-356; The manufacture of coke, by J. D. Weeks, pp. 357-402. Calendar year 1892, 1893: Coal, by E. W. Parker, pp. 263-550; The manufacture of coke, by J. D. Weeks, pp. 551-602. Calendar year 1893, 1894: Coal, by E. W. Parker, pp. 187-414; Manufacture of coke, by J. D. Weeks, pp. 415-460.

Mineral Resources of the United States, 1894, nonmetallic products. Sixteenth Ann. Rept., pt. 4, 1895: Coal, by E. W. Parker, pp. 1-217; Manufacture of coke, by J. D. Weeks, pp. 218-304; Origin, distribution, and commercial value of peat deposits, by N. S. Shaler, pp. 305-314.

Mineral Resources of the United States, 1895. Seventeenth Ann. Rept., pt. 3, 1896: Coal, by E. W. Parker, pp. 285-542; Coke, by J. D. Weeks, pp. 543-620.

^aFor publications on coal in Alaska, see Bulletin No. 335, 1908, pp. 130-133.

Mineral Resources of the United States, 1896. Eighteenth Ann. Rept., pt. 5, 1897: Coal, by E. W. Parker, pp. 351-632; Coke, by E. W. Parker, pp. 659-746.

Mineral Resources of the United States, 1897. Nineteenth Ann. Rept., pt. 6, 1898: Coal, by E. W. Parker, pp. 273-543; Coke, by E. W. Parker, pp. 545-642.

Mineral Resources of the United States, 1898. Twentieth Ann. Rept., pt. 6, 1899: Coal, by E. W. Parker, pp. 295-507; Coke, by E. W. Parker, pp. 509-608.

Mineral Resources of the United States, 1899. Twenty-first Ann. Rept., pt. 6, 1901: Coal, by E. W. Parker, pp. 321-519; Coke, by E. W. Parker, pp. 521-633.

Mineral Resources of the United States. David T. Day. Calendar year 1900, 1901: Coal, by E. W. Parker, pp. 273-457; Coke, by E. W. Parker, pp. 459-536. Calendar year 1901, 1902: Coal, by E. W. Parker, pp. 279-449; Coke, by E. W. Parker, pp. 451-523. Calendar year 1902, 1904: Coal, by E. W. Parker, pp. 289-447; Coke, by E. W. Parker, pp. 449-515. Calendar year 1903, 1904: Coal, by E. W. Parker, pp. 351-538; Coke, by E. W. Parker, pp. 539-608. Calendar year 1904, 1905: Coal, by E. W. Parker, pp. 381-577; Coke, by E. W. Parker, pp. 579-648; Peat, by H. H. Hindshaw, pp. 1229-1234. Calendar year 1905, 1906: Coal, by E. W. Parker, pp. 453-714; Coke, by E. W. Parker, pp. 715-766; Peat, by M. R. Campbell, pp. 1319-1322. Calendar year 1906, 1907: Coal, by E. W. Parker, pp. 563-753; Coke, by E. W. Parker, pp. 754-809; Peat, by M. R. Campbell, pp. 1211-1212. Calendar year 1907, 1908: Coal, by E. W. Parker, pt. 2, pp. 5-222; Coal briquetting in 1907, by E. W. Parker, pt. 2, pp. 223-228; Coke, by E. W. Parker, pt. 2, pp. 229-290.

TECHNOLOGIC.

Preliminary report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1894, E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. Bull. No. 261, 1905. 172 pp.

Preliminary report on the operations of the fuel-testing plant of the United States Geological Survey at St. Louis, Mo., 1905. J. A. Holmes, in charge. Bull. No. 290, 1906. 240 pp.

Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904. E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge. Prof. Paper No. 48, 1906. (In three parts.) 1492 pp.

The present status of the producer-gas power plant in the United States, by R. H. Fernald. Bull. No. 316, 1907, pp. 439-459.

Condition of the coal-briquetting industry in the United States, by E. W. Parker. Bull. No. 316, 1907, pp. 460-485.

The importance of uniform and systematic coal-mine sampling, by J. S. Burrows. Bull. No. 316, 1907, pp. 486-517.

Experimental work conducted in the chemical laboratory of the United States fuel-testing plant at St. Louis, Mo., by N. W. Lord. Bull. No. 323, 1907. 49 pp.

A study of four hundred steaming tests, by L. P. Breckenridge. Bull. No. 325, 1907. 196 pp.

Coal-mine accidents: their causes and prevention, by Clarence Hall, W. O. Snelling, and J. A. Holmes. Bull. No. 333, 1907. 21 pp.

The burning of coal without smoke in boiler plants, by D. T. Randall. Bull. No. 334, 1908. 26 pp.

Washing and coking tests of coal and cupola tests of coke, by Richard Moldenke, A. W. Belden, and G. R. Delamater, with introduction by J. A. Holmes. Bull. No. 336, 1908. 76 pp.

The purchase of coal under government and commercial specifications on the basis of its heating value, by D. T. Randall. Bull. No. 339, 1908. 27 pp.

Binders for coal briquets, by J. E. Mills. Bull. No. 343, 1908. 56 pp.

Mine sampling and chemical analyses of coals tested at the United States fuel-testing plant, Norfolk, Va., in 1907, by J. S. Burrows. Bull. No. 362, 1908. 23 pp.

Comparative tests of run-of-mine and briquetted coal on locomotives, including torpedo-boat tests and some foreign specifications for briquetted fuel, by W. F. M. Goss. Bull. No. 363, 1908. 57 pp.

Tests of coal and briquets as fuel for house-heating boilers, by D. T. Randall. Bull. No. 366, 1908. 44 pp.

Washing and coking tests of coal at the fuel-testing plant, Denver, Colo., by A. W. Belden, G. R. Delamater, and J. W. Groves. Bull. No. 368, 1909. 54 pp.

The prevention of mine explosions; report and recommendations, by Victor Watteyne, inspector-general of mines, Belgium; Carl Meissner, councillor for mines, Germany; and Arthur Desborough, H. M. inspector of explosives, England; with letter of transmittal by James Rudolph Garfield, Secretary of the Interior. Bull. No. 369, 1908. 11 pp.

AREAL.

GENERAL.

General account of the fresh-water morasses of the United States, with a description of the Dismal Swamp district of Virginia and North Carolina, by N. S. Shaler. Tenth Ann. Rept., 1890, pp. 303-304.

Discusses briefly the utilization of peat.

Stratigraphy of the bituminous coal field in Pennsylvania, Ohio, and West Virginia, by I. C. White. Bull. No. 65, 1891, 212 pp.

Origin, distribution, and commercial value of peat deposits, by N. S. Shaler. Sixteenth Ann. Rept., pt. 4, 1895, pp. 305-314.

General discussion.

The coal fields of the United States, by C. W. Hayes. Twenty-second Ann. Rept., pt. 3, 1902, pp. 7-24.

Distribution and geologic relations of the various coal fields in the United States, classification of coals, production, and marketing.

The northern Appalachian coal field, by David White, M. R. Campbell, and R. M. Haseltine. Twenty-second Ann. Rept., pt. 3, 1902, pp. 119-226.

The southern Appalachian coal field, by C. W. Hayes. Twenty-second Ann. Rept., pt. 3, 1902, pp. 227-263.

An account of the stratigraphy, distribution, and character of the coals of the Jellico, Chattanooga, and Birmingham districts, embracing parts of Kentucky, Tennessee, Georgia, and Alabama.

The eastern interior coal field, by G. H. Ashley. Twenty-second Ann. Rept., pt. 3, 1902, pp. 265-305.

An account of the coal field embracing parts of Indiana, Illinois, and Kentucky.

The western interior coal field, by H. F. Bain. Twenty-second Ann. Rept., pt. 3, 1902, pp. 333-366.

An account of the coal field occupying parts of Missouri, Kansas, Nebraska, and Iowa.

The southwestern coal field, by Joseph A. Taff. Twenty-second Ann. Rept., pt. 3, 1902, pp. 367-413.

An account of the coals of Arkansas, Indian Territory, and northern Texas.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415-471.

The coal fields of the Pacific coast, by George Otis Smith. Twenty-second Ann. Rept., pt. 3, 1902, pp. 473-513.

An account of the coals occurring in Washington, California, and Oregon.

Coal fields of the United States, by C. W. Hayes. Bull. No. 213, 1903, pp. 257-269.

A general account of the distribution and geologic relations of the coal fields, and the classification and marketing of coals.

Lignites of the middle and upper Missouri Valley, by E. F. Burchard. Bull. No. 225, 1904, pp. 276-288.

Describes the occurrence and character of lignite deposits in Dakota County, Nebraska, and in North Dakota.

Preliminary report on the geology and underground water resources of the central Great Plains, by N. H. Darton. Prof. Paper No. 32, 1905, pp. 372-379.

Gives a general account of the occurrence of coal in Colorado, Wyoming, South Dakota, and Nebraska.

Field work, by M. R. Campbell. Bull. No. 261, 1905, pp. 18-29.

Field work, by M. R. Campbell. Prof. Paper No. 48, pt. 1, 1906, pp. 156-173.

Survey work on coal during 1905, by M. R. Campbell. Bull. No. 285, 1906, pp. 203-210.

Gives a short account of geologic work on coal areas in 1905, of the work of the fuel-testing division, and of the classification of coals.

Contributions to economic geology, 1906, pt. 2. Coal, lignite, and peat, by M. R. Campbell and others. Bull. No. 316, 1907. 542 pp.

Classified list of papers dealing with coal, coke, lignite, and peat, contained in publications of U. S. Geol. Survey, by W. T. Lee and J. M. Nickles. Bull. No. 316, 1907, pp. 518-532.

Map of coal fields of the United States, by Marius R. Campbell, 1908.

Gives areas, production, and estimated original tonnage of coal fields

Contributions to economic geology, 1907, pt. 2. Coal and lignite, by M. R. Campbell and others. Bull. No. 341, 1909.

ALABAMA.

The coal measures of Alabama, by E. A. Smith. Mineral Resources U. S. for 1892, 1893, pp. 293-300.

Stevenson folio, Alabama-Georgia-Tennessee, description, by C. W. Hayes. Geologic Atlas U. S., folio 19, 1895.

Gadsden folio, Alabama, description, by C. W. Hayes. Geologic Atlas U. S., folio 35, 1896.

The southern Appalachian coal field, by C. W. Hayes. Twenty-second Ann. Rept., pt. 3, 1902, pp. 227-263.

An account of the stratigraphy, distribution, and character of the coals of the Jellico, Chattanooga, and Birmingham districts embracing parts of Kentucky, Tennessee, Georgia, and Alabama.

The Warrior coal basin in the Brookwood quadrangle, Alabama, by Charles Butts. Bull. No. 260, 1905, pp. 357-381.

The Warrior coal basin in the Birmingham quadrangle, Alabama, by Charles Butts. Bull. No. 285, 1906, pp. 211-222.

The northern part of the Cahaba coal field, Alabama, by Charles Butts. Bull. No. 316, 1907, pp. 76-115.

ARIZONA.

Report of work done in the division of chemistry and physics mainly during the fiscal year 1884-85. Bull. No. 27, 1886, p. 74.

Gives analyses of coal from Deer Creek Valley, Ariz.

The Deer Creek coal field, Arizona, by M. R. Campbell. Bull. No. 225, 1904, pp. 240-258.

ARKANSAS.

The coal fields of Arkansas, by J. C. Branner. Mineral Resources U. S. for 1892, 1893, pp. 303-306.

Preliminary report on the Camden coal field of southwestern Arkansas, by J. A. Taff. Twenty-first Ann. Rept., pt. 2, 1900, pp. 313-329.

The southwestern coal field, by J. A. Taff. Twenty-second Ann. Rept., pt. 3, 1902, pp. 367-413.

An account of the coals of Arkansas, Indian Territory, and northern Texas.

Fayetteville folio, Arkansas-Missouri, description, by G. I. Adams and E. O. Ulrich. Geologic Atlas U. S., folio 119, 1905, p. 6.

The Arkansas coal field, by A. J. Collier. Bull. No. 316, 1907, pp. 137-160.

The Arkansas coal field, by A. J. Collier, with reports on the paleontology by David White and G. H. Girty. Bull. No. 326, 1907. 158 pp.

Winslow folio, Arkansas-Indian Territory; description, by A. H. Purdue. Geologic Atlas U. S., folio 154, 1907. 6 pp.

CALIFORNIA.

The coal deposits of California, by H. W. Turner. Mineral Resources U. S. for 1892, 1893, pp. 308-310.

Sacramento folio, California; description, by Waldemar Lindgren. Geologic Atlas U. S., folio 5, 1894.

Jackson folio, California; description, by H. W. Turner. Geologic Atlas U. S., folio 11, 1894.

Lassen Peak folio, California; description, by J. S. Diller. Geologic Atlas U. S., folio 15, 1895.

Marysville folio, California; description, by Waldemar Lindgren and H. W. Turner. Geologic Atlas U. S., folio 17, 1895.

The coal fields of the Pacific coast, by G. O. Smith. Twenty-second Ann. Rept., pt. 3, 1902, pp. 473-513.

An account of the coals occurring in Washington, California, and Oregon.

Coal in the Mount Diablo Range, Monterey County, Cal., by Ralph Arnold. Bull. No. 285, 1906, pp. 223-225.

Coal of Stone Canyon, Monterey County, Cal., by M. R. Campbell. Bull. No. 316, 1907, pp. 435-438.

COLORADO.

A report of work done in the division of chemistry and physics mainly during the fiscal year 1888-'89, by F. W. Clarke. Bull. No. 64, 1890, p. 55.

Gives analyses of coals from Gunnison County, Colo.

Coal fields of Colorado, by R. C. Hills. Mineral Resources U. S. for 1892, 1893, pp. 319-365.

Anthracite-Crested Butte folio, Colorado; description of the sedimentary formations, by G. H. Eldridge. Geologic Atlas U. S., folio 9, 1894.

Geology of the Denver Basin in Colorado; economic geology, by G. H. Eldridge. Monograph XXVII, 1896, pp. 317-387.

Elmoro folio, Colorado; description, by R. C. Hills. Geologic Atlas U. S., folio 58, 1899.

La Plata folio, Colorado; economic geology, by C. W. Purington. Geologic Atlas U. S., folio 60, 1899, p. 14.

Walsenburg folio, Colorado; description, by R. C. Hills. Geologic Atlas U. S., folio 68, 1900, pp. 4-5.

Spanish Peaks folio, Colorado; description, by R. C. Hills. Geologic Atlas U. S., folio 71, 1901, pp. 4-6.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415-471.

Preliminary report on the geology and underground water resources of the central Great Plains, by N. H. Darton. Prof. Paper No. 32, 1905, pp. 372-379.

Gives a general account of the occurrence of coal in Colorado, Wyoming, South Dakota, and Nebraska.

The Yampa coal field, Routt County, Colo., by N. M. Fenneman and H. S. Gale. Bull. No. 285, 1906, pp. 226-239.

The Durango-Gallup coal field of Colorado and New Mexico, by F. C. Schrader. Bull. No. 285, 1906, pp. 241-258.

The Yampa coal field, Routt County, Colorado, by N. M. Fenneman and H. S. Gale. With a chapter on the character and use of the Yampa coals by M. R. Campbell. Bull. No. 297, 1906. 96 pp.

Coal fields of the Danforth Hills and Grand Hogback, in northwestern Colorado, by H. S. Gale. Bull. No. 316, 1907, pp. 264-301.

The Book Cliffs coal field between Grand River, Colo., and Sunnyside, Utah, by G. B. Richardson. Bull. No. 316, 1907, pp. 302-320.

The Durango coal district, Colorado, by J. A. Taff. Bull. No. 316, 1907, pp. 321-337.

A reconnaissance survey of the western part of the Durango-Gallup coal field of Colorado and New Mexico, by M. K. Shaler. Bull. No. 316, 1907, pp. 376-426.

Ouray folio, Colorado; description, by Whitman Cross, Ernest Howe, and J. D. Irving. Geologic Atlas U. S., folio 153, 1907. Coal, by Whitman Cross, p. 19.

Coal fields of northwestern Colorado and northeastern Utah, by H. S. Gale. Bull. No. 341, 1909, pp. 283-315.

The Grand Mesa coal field, Colorado, by W. T. Lee. Bull. No. 341, 1909, pp. 316-334.

Reconnaissance of the Book Cliffs coal field, by G. B. Richardson. Bull. No. 371, 1909. 53 pp.

GEORGIA.

Ringgold folio, Georgia-Tennessee; descriptive text, by C. W. Hayes. Geologic Atlas U. S., folio 2, 1894.

Stevenson folio, Alabama-Georgia-Tennessee; description, by C. W. Hayes. Geologic Atlas U. S., folio 19, 1895.

The southern Appalachian coal field, by C. W. Hayes. Twenty-second Ann. Rept., pt. 3, 1902, pp. 227-263.

An account of the stratigraphy, distribution, and character of the coals of the Jellico, Chattanooga and Birmingham districts, embracing parts of Kentucky, Tennessee, Georgia, and Alabama.

IDAHO.

Boise folio, Idaho; description, by Waldemar Lindgren. Geologic Atlas U. S., folio 45, 1898.

The Rocky Mountain coal fields, by L. S. Storrs. Twenty-second Ann. Rept., pt. 3, 1902, pp. 415-471.

ILLINOIS.

Danville folio, Illinois-Indiana; description, by M. R. Campbell. Geologic Atlas U. S., folio 67, 1900, pp. 6-7.

The eastern interior coal field, by G. H. Ashley. Twenty-second Ann. Rept., pt. 3, 1902, pp. 265-305.

An account of the coal field embracing parts of Indiana, Illinois, and Kentucky.

Recent work in the coal field of Indiana and Illinois, by M. L. Fuller and G. H. Ashley. Bull. No. 213, 1903, pp. 284-293.

Patoka folio, Indiana-Illinois; description, by M. L. Fuller and F. G. Clapp. Geologic Atlas U. S., folio 105, 1904, pp. 7-9.

Coal investigation in the Saline-Gallatin field, Illinois, and the adjoining area, by F. W. De Wolf. Bull. No. 316, 1907, pp. 116-136.

INDIANA.

Danville folio, Illinois-Indiana; description, by M. R. Campbell. Geologic Atlas U. S., folio 67, 1900, pp. 6-7.

The eastern interior coal field, by G. H. Ashley. Twenty-second Ann. Rept., pt. 5, 1902, pp. 265-305.

An account of the coal field embracing parts of Indiana, Illinois, and Kentucky.

Ditney folio, Indiana; economic geology, by G. H. Ashley. Geologic Atlas U. S., folio 84, 1902, p. 7.

Recent work in the coal field of Indiana and Illinois, by M. L. Fuller and G. H. Ashley. Bull. No. 213, 1903, pp. 284-293.

Patoka folio, Indiana-Illinois; description, by M. L. Fuller and F. G. Clapp. Geologic Atlas U. S., folio 105, 1904, pp. 7-9.

INDIAN TERRITORY. See OKLAHOMA.

IOWA.

Sketch of the coal deposits of Iowa, by C. R. Keyes. Mineral Resources U. S. for 1892, 1893, pp. 398-404.

The western interior coal field, by H. F. Bain. Twenty-second Ann. Rept., pt. 3, 1902, pp. 333-366.

An account of the coal field occupying portions of Missouri, Kansas, Nebraska, and Iowa.

KANSAS.

The western interior coal field, by H. F. Bain. Twenty-second Ann. Rept., pt. 3, 1902, pp. 333-366.

An account of the coal field occupying portions of Missouri, Kansas, Nebraska, and Iowa.

Stratigraphy and paleontology of the upper Carboniferous rocks of the Kansas section, by G. I. Adams, G. H. Girty, and David White. Bull. No. 211, 1903, 123 pp.

Includes notes on the occurrence of coal beds.

Economic geology of the Iola quadrangle, Kansas, by G. I. Adams, E. Haworth, and W. R. Crane. Bull. No. 238, 1904, pp. 74-75.

Notes the occurrence of coal of no economic value.

Economic geology of the Independence quadrangle, Kansas, by F. C. Schrader and E. Haworth. Bull. No. 296, 1906. Coal, pp. 48-52.

Joplin district folio, Missouri-Kansas; description, by W. S. T. Smith and C. E. Siebenthal. Geologic Atlas U. S., folio 148, 1907, pp. 19-20.

Independence folio; description, by F. C. Schrader. Geologic Atlas U. S., folio 159, 1908, p. 6.

KENTUCKY.

The coal fields of Kentucky, by J. R. Proctor. Mineral Resources U. S. for 1892, 1893, pp. 415-417.

Geology of the Big Stone Gap coal field of Virginia and Kentucky, by M. R. Campbell. Bull. No. 111, 1893, 106 pp.

Estillville folio, Kentucky-Virginia-Tennessee; description, by Mr. R. Campbell. Geologic Atlas U. S., folio 12, 1894.

Richmond folio, Kentucky; description, by M. R. Campbell. Geologic Atlas U. S. folio 46, 1898.

London folio, Kentucky; description, by M. R. Campbell. Geologic Atlas U. S., folio 47, 1898.

The southern Appalachian coal field, by C. W. Hayes. Twenty-second Ann. Rept., pt. 3, 1902, pp. 227-263.

An account of the stratigraphy, distribution, and character of the coals of the Jellico, Chattanooga, and Birmingham districts, embracing parts of Kentucky, Tennessee, Georgia, and Alabama.

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An account of the coal field embracing parts of Indiana, Illinois, and Kentucky.

The Cumberland Gap coal field of Kentucky and Tennessee, by G. H. Ashley. Bull. No. 225, 1904, pp. 259-275.

Coal resources of the Kenova quadrangle, by W. C. Phalen. Bull. No. 285, 1906, pp. 259-268.

Geology and mineral resources of part of the Cumberland Gap coal field, Kentucky, by G. H. Ashley and L. C. Glenn. Prof. Paper No. 49, 1906. 239 pp.

The Elkhorn coal field, Kentucky, by R. W. Stone. Bull. No. 316, 1907, pp. 42-54.

Coal resources of the Russell Fork basin in Kentucky and Virginia, by R. W. Stone. Bull. No. 348, 1908. 127 pp.

Economic geology of the Kenova quadrangle, Kentucky, Ohio, and West Virginia. by W. C. Phalen. Bull. No. 349, 1908. 158 pp.

MAINE.

Rockland folio, Maine; description, by E. S. Bastin. Geologic Atlas U. S., folio 158, 1908, p. 14.

Peat deposits of Maine, by E. S. Bastin and C. A. Davis. Bull. No. 376, 1909. 127 pp.

MARYLAND.

Piedmont folio, West Virginia-Maryland; description, by N. H. Darton and J. A. Taff. Geologic Atlas U. S., folio 28, 1896.

The bituminous coal field of Maryland, by David White. Twenty-second Ann. Rept., pt. 3, 1902, pp. 201-214.

Accident-Grantsville folio, Maryland-Pennsylvania-West Virginia; description, by G. C. Martin. Geologic Atlas U. S., folio 160, 1908, pp. 11-13.

MICHIGAN.

The northern interior coal field, by A. C. Lane. Twenty-second Ann. Rept., pt. 3, 1902, pp. 307-331.

Ann Arbor folio, Michigan; description, by I. C. Russell and Frank Leverett. Geologic Atlas U. S., folio 155, 1908, pp. 8-9.

MISSOURI.

The coal measures of Missouri, by Arthur Winslow. Mineral Resources U. S. for 1892, 1893, pp. 429-436.

The western interior coal field, by H. F. Bain. Twenty-second Ann. Rept., pt. 3, 1902, pp. 333-366.

An account of the coal field occupying portions of Missouri, Kansas, Nebraska, and Iowa.

Joplin district folio, Missouri-Kansas; description, by W. S. T. Smith and C. E. Siebenthal. Geologic Atlas U. S., folio 148, 1907, pp. 19-20.

MONTANA.

The Laramie and the overlying Livingston formation in Montana, by W. H. Weed. Bull. No. 105, 1893, p. 105.

A brief statement regarding the occurrence and character of the coal beds.

Livingston folio, Montana; description, by J. P. Iddings and W. H. Weed. Geologic Atlas U. S., folio 1, 1894.

Three Forks folio, Montana; description, by A. C. Peale. Geologic Atlas U. S., folio 24, 1896.

Geology and mineral resources of the Judith Mountains of Montana, by W. H. Weed and L. V. Pirsson. Eighteenth Ann. Rept., pt. 3, 1898, pp. 614-616.

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